U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: Acceptable Methods, Techniques, and Practices—Aircraft Inspection And Repair

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*1. **PURPOSE.** This advisory circular contains methods, techniques, and practices acceptable to the Administrator for inspection and repair to civil aircraft, only when there is no manufacturer repair or maintenance instructions. This data generally pertains to minor repairs. It may be used as a basis for FAA data approval for major repairs. This data may be used as approved data when: (1) The user has determined that it is appropriate to the product being repaired; (2) directly applicable to the repair being made; and (3) not contrary to manufacturer's data. *

2. **CANCELLATION.** The Advisory Circular 43.13-1 dated 1965 is canceled.

3. **REFERENCE.** FAR Part 43 requires that methods, techniques, and practices acceptable to the Administrator must be used for inspection and repair to civil aircraft. Techniques, practices, and methods other than those prescribed in this advisory circular may be used providing they are acceptable to the Administrator. FAA Inspectors are prepared to answer questions that may arise in this regard. Persons engaged in inspection and repair of civil aircraft should be familiar with FAR Part 43, Maintenance, Preventive Maintenance, Rebuilding, and Alteration, and Subparts A, D, and E of FAR Part 65, Certification: Airmen Other Than Flight Crewmembers, and the applicable airworthiness requirements under which the aircraft was type certificated.

4. **HOW TO GET THE HANDBOOK.** Order additional copies of this publication from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Identify the publication in your order as:

FAA AC No. 43.13-1A
Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair, 1972.

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Chapter 1. AIRCRAFT WOOD STRUCTURES

Section 1. MATERIALS AND PRACTICES

1. MATERIALS. Three forms of wood are commonly used in aircraft: solid wood, plywood, and laminated wood. Although several kinds of modified wood are sometimes used for special purposes, these three forms constitute the bulk of all wood aircraft construction materials.

a. *Quality of Wood.* All wood and plywood used in the repair of aircraft structures should be of aircraft quality. Figure 1.2 lists the permissible variations in characteristics and properties of aircraft wood.

b. *Species Substitution.* The species used to repair a part should be the same as that of the original whenever possible; however, permissible substitutes are given in figure 1.2.

c. *Effects of Shrinkage.* When the moisture content of wood is lowered, its dimensions decrease. The dimensional change is greatest in a tangential direction (across the fibers and parallel to the growth rings), somewhat less in a radial direction (across the fibers and perpendicular to the growth rings), and is negligible in a longitudinal direction (parallel to the fibers). These dimensional changes can have several detrimental effects upon a wood structure, such as loosening of fittings and wire bracing and checking or splitting of wood members.

A few suggestions for minimizing these shrinkage effects are:

(1) Use bushings that are slightly short so that when the wood member shrinks the bushings do not protrude and the fittings may be tightened firmly against the member.

(2) Gradually drop off plywood face plates either by feathering or by shaping as shown in figure 1.1.

2. REPLACEMENT OF DRAINHOLES AND SKIN STIFFENERS. Whenever repairs are made that require replacing a portion that includes drainholes, skin stiffeners, or any other items, the repaired portion must be provided with similar drainholes, skin stiffeners, or items of the same dimensions in the same location. Reinforcing, under skin repairs, that interferes with the flow of water from some source, such as inspection holes, is to be provided with drainholes at the lowest points.

3. CONTROL SURFACE FLUTTER PRECAUTIONS. When repairing control surfaces, especially on high-performance airplanes, care must be exer-

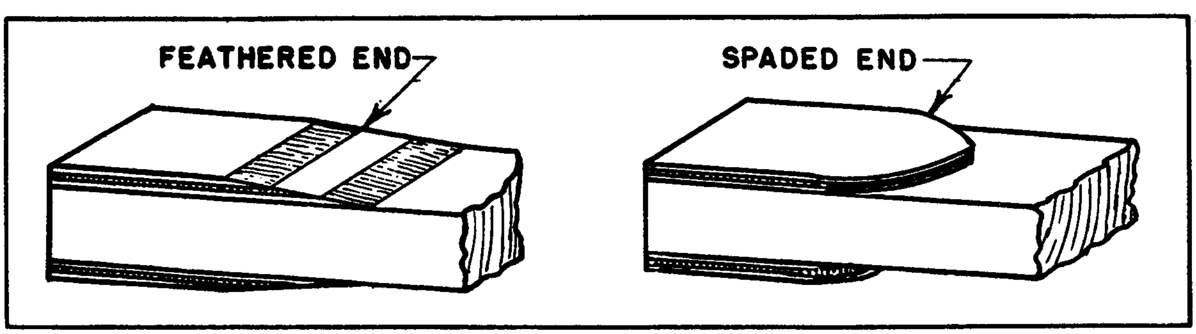

FIGURE 1.1.—Tapering of face plates.

FIGURE 1.2.—Selection and properties of aircraft wood.

Species of wood	Strength properties as compared to spruce	Maximum permissible grain deviation (slope of grain)	Remarks
1	2	3	4
Spruce (Picea) Sitka (P. Sitchensis) Red (P. Rubra) White (P. Glauca).	100%	1:15	Excellent for all uses. Considered as standard for this table.
Douglas Fir (Pseudotsuga Taxifolia).	Exceeds spruce.	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Difficult to work with hand tools. Some tendency to split and splinter during fabrication and considerable more care in manufacture is necessary. Large solid pieces should be avoided due to inspection difficulties. Gluing satisfactory.
Nobe Fir (Abies Nobiles).	Slightly exceeds spruce except 8 percent deficient in shear.	1:15	Satisfactory characteristics with respect to workability, warping, and splitting. May be used as direct substitute for spruce in same sizes providing shear does not become critical. Hardness somewhat less than spruce. Gluing satisfactory.
Western Hemlock (Tsuga Heterophylla).	Slightly exceeds spruce.	1:15	Less uniform in texture than spruce. May be used as direct substitute for spruce. Upland growth superior to lowland growth. Gluing satisfactory.
Pine, Northern White (Pinus Strobus).	Properties between 85 percent and 96 percent those of spruce.	1:15	Excellent working qualities and uniform in properties but somewhat low in hardness and shock-resisting capacity. Cannot be used as substitute for spruce without increase in sizes to compensate for lesser strength. Gluing satisfactory.
White Cedar, Port Orford (Charaecyparis Lawsoniana).	Exceeds spruce.	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Easy to work with hand tools. Gluing difficult but satisfactory joints can be obtained if suitable precautions are taken.
Poplar, Yellow (Liriodendrow Tulipifera).	Slightly less than spruce except in compression (crushing) and shear.	1:15	Excellent working qualities. Should not be used as a direct substitute for spruce without carefully accounting for slightly reduced strength properties. Somewhat low in shock-resisting capacity. Gluing satisfactory.

(See notes following table.)

Notes for figure 1.2.

1. *Defects Permitted.*
   a. *Cross grain.* Spiral grain, diagonal grain, or a combination of the two is acceptable providing the grain does

not diverge from the longitudinal axis of the material more than specified in column 3. A check of all four faces of the board is necessary to determine the amount of divergence. The direction of free-flowing ink will frequently assist in determining grain direction.

b. *Wavy, curly, and interlocked grain.* Acceptable, if local irregularities do not exceed limitations specified for spiral and diagonal grain.

c. *Hard knots.* Sound hard knots up to ⅜-inch in maximum diameter are acceptable providing: (1) they are not in projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of flanges of box beams (except in lowly stressed portions); (2) they do not cause grain divergence at the edges of the board or in the flanges of a beam more than specified in column 3; and (3) they are in the center third of the beam and are not closer than 20 inches to another knot or other defect (pertains to ⅜-inch knots—smaller knots may be proportionately closer). Knots greater than ¼-inch must be used with caution.

d. *Pin knot clusters.* Small clusters are acceptable providing they produce only a small effect on grain direction.

e. *Pitch pockets.* Acceptable, in center portion of a beam providing they are at least 14 inches apart when they lie in the same growth ring and do not exceed 1½ inch length by ⅛-inch width by ⅛-inch depth and providing they are not along the projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of the flanges of box beams.

f. *Mineral streaks.* Acceptable, providing careful inspection fails to reveal any decay.

2. *Defects Not Permitted.*

a. *Cross grain.* Not acceptable, unless within limitations noted in 1a.

b. *Wavy, curly, and interlocked grain.* Not acceptable, unless within limitations noted in 1b.

c. *Hard knots.* Not acceptable, unless within limitations noted in 1c.

d. *Pin knot clusters.* Not acceptable, if they produce large effect on grain direction.

e. *Spike knots.* These are knots running completely through the depth of a beam perpendicular to the annual rings and appear most frequently in quartersawed lumber. Reject wood containing this defect.

f. *Pitch pockets.* Not acceptable, unless within limitations noted in 1e.

g. *Mineral streaks.* Not acceptable, if accompanied by decay (see 1f).

h. *Checks, shakes, and splits.* Checks are longitudinal cracks extending, in general, across the annual rings. Shakes are longitudinal cracks usually between two annual rings. Splits are longitudinal cracks induced by artificially induced stress. Reject wood containing these defects.

i. *Compression wood.* This defect is very detrimental to strength and is difficult to recognize readily. It is characterized by high specific gravity; has the appearance of an excessive growth of summer wood; and in most species shows but little contrast in color between spring wood and summer wood. In doubtful cases reject the material, or subject samples to a toughness machine test to establish the quality of the wood. Reject all material containing compression wood.

j. *Compression failures.* This defect is caused from the wood being overstressed in compression due to natural forces during the growth of the tree, felling trees on rough or irregular ground, or rough handling of logs or lumber. Compression failures are characterized by a buckling of the fibers that appear as streaks on the surface of the piece substantially at right angles to the grain, and vary from pronounced failures to very fine hairlines that require close inspection to detect. Reject wood containing obvious failures. In doubtful cases reject the wood, or make a further inspection in the form of microscopic examination or toughness test, the latter means being the more reliable.

k. *Decay.* Examine all stains and discolorations carefully to determine whether or not they are harmless, or in a stage of preliminary or advanced decay. All pieces must be free from rot, dote, red heart, purple heart, and all other forms of decay.

cised that the repairs do not involve the addition of weight aft of the hinge line. Such a procedure may adversely disturb the dynamic and static balance of the surface to a degree which would induce flutter. As a general rule, it will be necessary to repair control surfaces in such a manner that the structure is identical to the original so that the weight distribution and resulting mass balance are not affected in any way.

4. GLUING PRECAUTIONS. Satisfactory glue joints in aircraft will develop the full strength of wood under all conditions of stress. To produce this result, the gluing operation must be carefully controlled so as to obtain a continuous, thin, uniform film of solid glue in the joint with adequate adhesion to both surfaces of the wood. Some of the more important conditions involve:

a. Properly prepared wood surfaces.

b. Glue of good quality, properly prepared.

c. Good gluing technique.

5. PREPARATION OF WOOD SURFACES FOR GLUING. It is recommended that no more than 8 hours be permitted to elapse between final surfacing and gluing. The gluing surfaces should be machined smooth and true with planers, jointers, or special miter saws. Planer marks, chipped or loosened grain, and other surface irregularities will not be permitted. Sandpaper must never be used to smooth softwood surfaces that are to be glued. Sawed surfaces must approach well-planed surfaces in uniformity, smoothness, and freedom from crushed fibers.

a. ***Tooth-planing,*** or other means of roughening smooth well-planed surfaces of normal wood before gluing, is not recommended. Such treatment of well-planed wood surfaces may result in local irregularities and objectionable rounding of edges. While sanding of planed surfaces is not recommended for softwoods, sanding is a valuable aid in improving the gluing characteristics of some hard plywood surfaces, wood that has been compressed through exposure to high pressure and temperatures, resin-impregnated wood (impreg and compreg), and laminated paper plastic (papreg).

b. ***Wood surfaces for gluing*** should be free from oil, wax, varnish, shellac, lacquer, enamel, dope, sealers, paint, dust, dirt, oil, glue, crayon marks, and other extraneous materials.

c. ***Wetting tests*** are useful as a means of detecting the presence of wax. Drops of water placed on the surface of wax-coated wood do not spread or wet the wood. At present, preliminary gluing tests appear to be the only positive means of actually determining the gluing characteristics of plywood surfaces.

6. GLUES. Glues used in aircraft repair fall into two general groups: casein glues and resin glues. Any glue that meets the performance requirements of applicable United States military specifications or has previously been accepted by the Federal Aviation Administration (FAA) is satisfactory for use in certificated civil aircraft. In all cases, glues are to be used strictly in accordance with the glue manufacturer's recommendations.

a. ***Casein Glues.*** Casein glues have been widely used in wood aircraft repair work. The forms, characteristics, and properties of water-resistant casein glues have remained substantially the same for many years, except for the addition of preservatives. Casein glues for use in aircraft should contain suitable preservatives such as the chlorinated phenols and their sodium salts to increase their resistance to organic deterioration under high-humidity exposures. Most casein glues are sold in powder form ready to be mixed with water at ordinary room temperatures.

* **Caution**

Casein glue deteriorates over the years after exposure to moisture in the air and temperature variations. Many of the modern glues are incompatible with casein glue. If a joint that has been glued with casein is to be reglued with resin glue, all traces of the casein must be scraped off before the new glue is applied. If any alkalinity of any casein glue is left, it may cause the new glue to fail to cure properly.

b. ***Plastic resin glue.*** Plastic resin glue, a powdered glue that is mixed with water, is perhaps the most popular glue used today for aircraft woodwork. It must be mixed in the exact proportions specified by the manufacturer.

Typically this glue is prepared by mixing five parts by volume of the powdered glue with two parts, by volume, of cold water. This is the same as 10 parts of powder and 6 parts of water by weight. Pour a small amount of water into the powder and stir into a heavy paste and then add the remainder of the water. Continue to stir until the mixture is about as thick as heavy cream. The glue is ready for use as soon as it is mixed. Figure 1.2a shows the working timetable for plastic resin glues.

c. ***Resorcinol glue.*** This is a two-part synthetic resin glue consisting of resin and a hardener and is the most water resistant of the glues used. The appropriate amount (per manufacturer's instruction) of hardener is added to the resin, and it is stirred until it is consistently mixed; the glue is now ready for immediate use.

Caution

Read and observe material safety data.

"7. [Deleted] — Change 3" *

* FIGURE 1.2a.—Plastic resin glue working timetable.

Condition	Temperature		
	70° F (21° C)	80° F (27° C)	90° F (32° C)
Mixture pot life (hours)	4 - 5	2 1/2 - 3 1/2	1 - 2
Maximum assembly time	15	10	5
Open (minutes)	15	10	5
Closed (minutes)	25	15	8
Pressure period (hours)	14	8	5

Note: Assembly must be maintained at a temperature of 70° F. or above to assure a satisfactory cure of the glue line. *

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nal finish. If dope or lacquer is used to complete the finish, the sealer coats should be dope-proof. Spar varnish or sealer conforming to Specification MIL-V-6894 is satisfactory.

41. FINISHING OF END GRAIN SURFACES. End grain surfaces, such as edges of plywood skins and holes in spars and other primary structural members, require careful protection. Sand these surfaces smooth. Apply two coats of a highly pigmented sealer, or one coat of wood filler, and one coat of clear sealer to end grain interior surfaces and cut holes. Exterior end grain surfaces (except those covered with doped fabric) require an additional (third) coat of clear sealer. A final coat of aluminized varnish may be applied to end grain surfaces. If the surfaces are to be finished with dope or lacquer, a dope-proof sealer similar to Specification MIL-V-6894 should be used.

Exposed end grain includes such surfaces as those around ventholes, inspection holes, fittings, and exposed scarfed or tapered surfaces such as those of tapered blocking.

42. FINISHING WITH FABRIC OR TAPE. To refinish with fabric or tape, it is first necessary to insure that paint has been removed from an area greater than that to be covered by the fabric.

a. *Apply two brush coats* of a dope-proof sealer similar to Specification MIL-V-6894, allowing the first coat to dry 2 hours and the second coat as least 6 hours. Follow with one coat of clear dope, and allow it to dry 45 minutes. Apply a second coat of clear dope and lay into the wet film a piece of pinked-edge airplane cloth. All air bubbles should be worked out by brushing to insure maximum adherence. Allow this to dry 45 minutes. Apply one brush coat to insure proper penetration, and at least one spray coat of clear dope, allowing each to dry 45 minutes. The dried spray coat may be sanded with fine sandpaper to obtain a smoother finish. Complete the refinishing of the surface by application of lacquer, enamel, or aluminized varnish as required to match the adjacent area.

b. *The size of the fabric patch* should be such as to extend at least 1/2 inch on each side of any crack or group of cracks, at least 1 inch on each side of a scarfed joint glue line, and at least 2 inches beyond any edge of a skin patch to insure proper adhesion.

*** 43. INSPECTION OF WOOD IN AIRCRAFT STRUCTURES.**

a. *Inspect for evidence of mildew.* This is evidence of excessive humidity and heat. Extensive mildew will attack the cellulose in the wood which will develop into dry rot.

b. *Inspect glue joints* for indication of loss of adhesion, i.e.;

(1) Opening up of joint — in joint cracks.

(2) Discoloration of glue joint — adverse chemical reaction in glue joint.

c. *Inspect for loosening of nails* in a scarf patch — this could be evidence of adverse movement developing in the spar.

d. *Inspect for evidence of wood shrinkage* at installation of fittings — loose bolts or screws.

e. *Inspect for evidence of wood being excessively wet* — immersed or water flow over structure or entrapped water. Fittings will be embedded in wood instead of flush.

f. *Inspect for evidence of cracking* — could be caused by excessive stress, excessively tight fittings or impact, or many other causes.

g. *Inspect for loss of finish* — could be from abrasion or deterioration of chemical stability. Loss of finish will permit attack by mildew, fungus, or oxidation.

h. *Inspect for fungus* — usually caused by "hot house" conditions; moisture, heat, and exposure to spores released by fungus in the storage areas.

i. *Inspect for dry rot* — loss of finish, mildew, fungus, excessive shrinkage, discoloration, and cracks. Wood crumbles under pressure.

j. *Inspect for excessive wood defects* — use figure 1-2 and notes to determine the correct standards. *

44.-53. RESERVED.

Chapter 2. AIRCRAFT METAL STRUCTURES

Section 1. REFERENCES AND PRECAUTIONARY MEASURES

54. REFERENCES. The following chapters of this AC should be referred to when accomplishing repairs to aircraft metal structures:

a. *Identification and Inspection of Materials.* Identification and inspection of materials should be conducted in accordance with Chapter 7.

b. *Corrosion Protection.* Corrosion protection treatment, cleaners, and paint removing should be accomplished in accordance with Chapter 6.

c. *Aircraft Hardware.* Acceptable means of attachment are listed in Chapter 5.

55. FLUTTER AND VIBRATION PRECAUTIONS. To prevent the occurrence of severe vibration or flutter of flight control surfaces during flight, precautions must be taken to stay within the design balance limitations when performing maintenance or repair.

a. *Balance Changes.* The importance of retaining the proper balance and rigidity of aircraft control surfaces cannot be underestimated. As a general rule, repair the control surface in such a manner that the structure is identical to the original so that the weight distribution is not affected in any way. In order to preclude the occurrence of flutter of the control surface in flight, a degree of static and/or dynamic balance is established for each model of aircraft. Under certain conditions, counter-balance weight is added forward of the hinge line to maintain balance. Remove or add balance weight only when necessary in accordance with the manufacturer's instructions, or obtain FAA approval. Flight testing may be required. Failure to check and retain control surface balance within the original or maximum allowable value could result in a serious flight hazard.

b. *Materials and Construction Techniques.* The development of new materials and techniques has made possible the use of control surfaces of less mass weight for a given area than some aircraft of older design. The effect of repair or weight change on the balance and center of gravity is proportionately greater on lighter surfaces than on the older designs. Since control surfaces on some models are balanced for flutter-free operation up to maximum speed for which the aircraft was originally designed, special attention, therefore, must be given to such surfaces relative to the effects of structural repairs and rework on their balance condition.

c. *Painting and Refinishing.* Special emphasis is directed to the effect indiscriminate application of extra coats of dope or paint has on the balance of control surfaces. Proper maintenance of control surface balance may require removal of dope or paint, down to the base coat, prior to application of finish coats. Consult the aircraft manufacturer's instructions relative to finishing and balance of control surfaces.

d. *Trapped Water or Ice.* Instances of flutter have occurred from unbalanced conditions caused by the collection of water or ice within the surface. Therefore, ventilation and drainage provisions must be checked and retained when maintenance is being done. Certain construction designs do not provide for ventilation and may collect moisture through condensation which will affect balance. In the event this condition is found, refer to the manufacturer's instructions for moisture removal.

e. *Trim Tab Maintenance.* In addition to unbalanced control surface, loose or vibrating trim tabs will increase wear of actuating mechanisms and hinge points which may develop serious flutter conditions. Most trim tabs are not balanced separately from the control surface. Minimum tab flutter is maintained through rigid actuating mechanisms. Trim tabs and their actuating mechanism are constructed as lightly as possible to keep the weight aft of the hinge line of the control surface as low as possible. Actuating mechanisms are highly susceptible to wear, deformation, and fatigue failures because of the buffeting nature of airflow over the tab mechanism. Trailing-edge play of the tab may increase, through wear of the mechanism, to an unsafe condition. Careful inspection of the tab and its mechanism should be conducted during overhaul and inspection periods. Compared to other systems on the aircraft, only a minor amount of tab-mechanism wear can be tolerated. * The total free play at the tab trailing edge should be less than the following. If the tab span does not exceed 35 percent of the span of the supporting control surface, the total free play shall not exceed 2 percent of the distance from the tab hinge line to the trailing edge of the tab perpendicular to the tab hinge line. If the tab span equals or exceeds 35 percent of the span of the supporting control surface, the total free play is not to exceed 1 percent of the distance from the tab hinge line to the trailing edge of the tab perpendicular to the tab hinge line. For example, a tab that has a chord of 4 inches would have a maximum permissible free play of 4 inches x .020 or .080 inches (total motion up and down) measured at the trailing edge. Correct any free * play in excess of this amount. Care must also be exercised during repair or rework to prevent stress concentration points or areas which could increase the fatigue susceptibility of the trim tab system.

56. BRAZING. Brazing may be used for repairs to primary aircraft structures only if brazing was originally approved for the particular application. Brazing is not suitable for repair of welds in steel structures due to lower strength values of the brazed joint as compared to welded joints. Brazing may be used in the repair of secondary structures.

Due to the large number of brazing alloys used, it is difficult to be certain that the material selected for repairing a brazed joint will result in a joint having the same strength characteristics as the original. In cases where it is necessary to apply copper alloy brazing material more than once on a steel surface, and particularly if temperatures over 2,000° F. are reached, there is a possibility that brazing metal may penetrate between the grains in the steel to an extent that may cause cracking. Copper brazing of steel is normally accomplished in a special furnace having a controlled atmosphere, and at a temperature so high that field repairs are seldom feasible. If copper brazing is attempted without a controlled atmosphere, the copper will probably not completely flow and fill the joint. Therefore, copper brazing in any other than appropriately controlled conditions is not recommended.

57.-67. RESERVED.

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Section 4. REPAIR OF LAMINATE STRUCTURES

115. GENERAL. There is a wide variation in the composition and structural application of laminates, and it is essential that these factors be given major consideration when any restoration activities are undertaken. To a similar extent, there also exist many types of laminate structure repairs that may or may not be suitable for a given condition. For this reason, it is important that the aircraft or component manufacturer's repair data be reviewed when determining what specific type of repair is permissible and appropriate for the damage at hand.

The materials used in the repair of laminate structures must preserve the strength, weight, aerodynamic characteristics, or electrical properties of the original part or assembly. This can best be accomplished by replacing damaged material with material of identical chemical composition or a substitute approved by the manufacturer.

In order to eliminate dangerous stress concentrations, avoid abrupt changes in cross-sectional areas. Whenever possible, for scarf joints and facings, make small patches round or oval-shaped, and round the corners of large repairs. Smooth and properly contour aerodynamic surfaces.

It is recommended that test specimens be prepared at the same time that the actual repair is accomplished. These can then be subjected to a destructive test to establish the quality of the adhesive bond in the repaired part. To make this determination valid, the specimens must be assembled with the same adhesive batch mixture and subjected to curing pressure, temperature, and time identical with those in the actual repair.

a. ***Fiberglass Laminate Repairs.*** The following repairs are applicable to fiberglass laminate used for fairings, covers, cowlings, honeycomb panel facings, etc. Prior to undertaking the repair, clean the repair area thoroughly with a castile soap and warm water. Remove any paint by wet or dry sanding methods. Bead blasting may be used but caution must be exercised to not abrade the surfaces excessively.

Superficial scars, scratches, surface abrasion, or rain erosion can generally be repaired by applying one or more coats of a suitable resin, catalyzed to cure at room temperature, to the abraded surface. The number of coats required will depend upon the type of resin and severity of the damage.

Damage not exceeding the first layer or ply of fiberglass laminate can be repaired by filling with a putty consisting of a compatible room-temperature-setting resin and clean short glass fibers. Before the resin sets, apply a sheet of cellophane over the repair area and work out any bubbles and excess resin. After the resin has cured, sand off any excess and prepare the area for refinishing.

Damage deep enough to seriously affect the strength of the laminate (usually more than the first ply or layer of fabric) may be repaired as illustrated in figure 2.37 below. Coat the

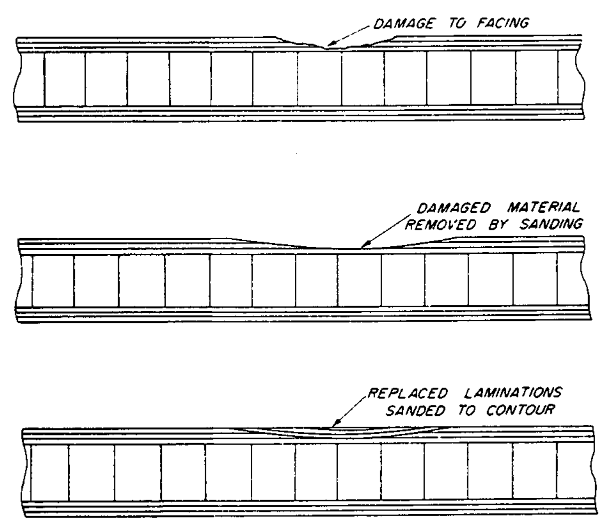

FIGURE 2.37.—Typical laminate (facing) repair.

Chapter 3. FABRIC COVERING

Section 1. PRACTICES AND PRECAUTIONS

127. TEXTILE MATERIALS. All fabric, surface tape, reinforcing tape, machine thread, lacing cord, etc., used for re-covering or repairing an aircraft structure must be high-grade aircraft textile material of at least as good quality and equivalent strength as those described in subparagraphs a through g.

a. *Aircraft Fabric.* Acceptable fabrics such as cotton and linen for covering wings, control surfaces, and fuselages are listed in figure 3.1. Fabrics conforming to the Aeronautical Material Specifications (AMS) incorporate a continuous marking showing the specification number to permit identification of the fabric in the field.

b. *Re-covering Aircraft.* Re-cover or repair aircraft with fabric of at least as good quality and equivalent strength as that originally used on the aircraft. However, in re-covering aircraft which were originally covered with low strength or so-called "glider cloth," it is considered more desirable to use Grade A or "intermediate" fabric conforming to AMS 3806 or 3804, as amended, respectively. Certain synthetic and fiberglass fabrics have been developed that are acceptable alternates to AMS 3806 or AMS 3804 fabric, providing the Supplemental Type Certificate (STC) installation instructions furnished with the material are followed. Specification MIL-C-9084, MIL-Y-1140C, and MIL-G-1140 materials in the untreated condition have equivalent strength characteristics to Technical Standard Order TSO-C15 material specifications.

c. *Reinforcing Tape.* Acceptable reinforcing *tape is listed in figure 3.2. Use reinforcing tape which meets specification MIL-T-5661. Reinforcing tape for lightweight fabric should be made from combed cotton yarn, should be unbleached, and should contain no more than 3.5 percent sizing, finishing, and other nonfibrous materials. Breaking strength should be not less than one half of that prescribed in figure 3.2. *

d. *Surface Tape.* Use surface tape (also finishing tape) having approximately the same properties as the fabric used. See figure 3.2.

e. *Lacing Cord.* Use lacing cord having a strength of at least 80 pounds double or 40 pounds single strand. See figure 3.2.

f. *Machine Thread.* Use machine thread having a strength of at least 5 pounds single strand. See figure 3.2.

g. *Hand-Sewing Thread.* Use hand-sewing thread having a strength of at least 14 pounds single strand. See figure 3.2.

128. COVERING PRACTICES. The method of fabric attachment should be identical, as far as strength and reliability are concerned, to the method used by the manufacturer of the airplane to be re-covered or repaired. Fabric may be applied so that either the warp or fill-threads are parallel to the line of flight. Either the envelope method or blanket method of covering is acceptable.

a. *Flutter Precautions.* When re-covering or repairing control surfaces, especially on high performance airplanes, make sure that dynamic and static balances are not adversely affected. Weight distribution and mass balance must be considered to preclude the possibility of induced flutter.

129. PREPARATION OF THE STRUCTURE FOR COVERING. One of the most important items in covering aircraft is proper preparation of the structure. Dopeproofing, covering edges which are likely to wear the fabric, preparation of plywood surfaces, and similar operations, if properly done, will do much toward insuring an attractive and long-lasting job.

a. *Dopeproofing.* Treat all parts of the structure which come in contact with doped fabric with a protective coating such as aluminum foil, dopeproof paint, or cellulose tape. Clad aluminum and stainless steel parts need not be dopeproofed.

b. *Chafe Points.* Cover all points of the structure, such as sharp edges, boltheads, etc., which are likely to chafe or wear the covering with doped-on fabric strips or cover with an adhesive tape. After the cover has been installed, reinforce the chafe points of the fabric by doping on fabric patches. Where a stronger reinforcement is required, apply a cotton duck or leather patch sewed to a fabric patch and then dope in place. Reinforce all portions of the fabric pierced by wires, bolts, or other projections.

c. *Inter-Rib Bracing.* Conventional wing ribs, which do not have permanent inter-rib bracing, should be bound in position by means of cotton tape running parallel to the beams. Apply the tape diagonally between the top and bottom capstrips of each successive rib approximately halfway between the front and rear beams. Apply the tape continuously from the butt rib to the tip rib with one turn of tape around each intermediate rib capstrip.

d. *Preparation of Plywood Surfaces for Covering.* Prior to covering plywood surfaces with fabric, prepare the surface by cleaning and applying sealer and dope.

(1) Cleaning. Sand all surface areas which have been smeared with glue in order to expose a clean wood surface. Remove loose deposits such as woodchips and sawdust. Remove oil or grease spots by carefully washing with naphtha.

(2) Applying of Sealer and Dope. Apply one brush coat or two dip coats (wiped) of a dopeproof sealer such as that conforming to Specification MIL-V-6894 thinned to 30 percent nonvolatile content and allow to dry 2 to 4 hours. Finally, before covering, apply two brush coats of clear dope allowing the first coat of dope to dry approximately 45 minutes before applying the second coat.

130. FABRIC SEAMS. Seams parallel to the line of flight are preferable; however, spanwise seams are acceptable.

a. *Sewed Seams.*

(1) Machine-sewn seams (parts D, E, and F of figure 3.3) should be of the folded fell or French fell types. Where salvage edges or pinked edges are joined, a plain lap seam is satisfactory.

(2) Begin hand sewing or tacking at the point where machine sewing or uncut fabric is again reached. Lock hand sewing at intervals of 6 inches, and finish the seam with a lock stitch and a knot (figure 3.4). At the point where the hand sewing or permanent tacking is necessary, cut the fabric so that it can be doubled under before sewing or permanent tacking is performed (figure 3.3 (C)). After hand sewing has been completed, remove the temporary tacks. In hand sewing, use a minimum of four stitches per inch.

(3) Cover a sewed spanwise seam on a metal- or wood-covered leading edge with pinked-edge surface tape at least 4 inches wide.

(4) Cover a sewed spanwise seam at the trailing edge with pinked-edge surface tape at least 3 inches wide. For aircraft with never-exceed speeds in excess of 200 m.p.h., cut notches at least 1 inch in depth and 1 inch in width in both edges of the surface tape when used to cover spanwise seams on trailing edges, especially the trailing edges of control surfaces. Space notches at intervals not exceeding 18 inches. On tape less than 3 inches wide, the notches should be 1/3 the tape width. In the event that the surface tape begins to separate because of poor adhesion or other causes, the tape will tear at a notched section, thus preventing progressive loosening of the entire length of the tape which could seriously affect the controlling of the aircraft.

(5) Cover a double-stitched lap joint with pinked-edge surface tape at least 4 inches wide.

(6) Make sewed spanwise seams on the upper or lower surface in a manner that the amount of protuberance is minimum. Cover the seam with pinked-edge tape at least 3 inches wide.

(7) Sewed seams parallel to the line of flight (chordwise) may be located over ribs; however, place the seam on the rib so that the lacing will not penetrate through the seam.

FIGURE 3.1.—Textile fabric used in aircraft covering.

Materials	Specification	Minimum tensile strength new (undoped)	Minimum tearing strength new (undoped)	Minimum tensile strength deteriorated (undoped)	Thread count per inch	Use and remarks
Airplane cloth mercerized cotton (Grade "A").	Society Automotive Engineers AMS 3806 (TSO-C15 references this spec.).	80 pounds per inch warp and fill.	5 pounds warp and fill.	56 pounds per inch.	80 min., 84 max. warp and fill.	For use on all aircraft. Required on aircraft with wing loadings greater than 9 p.s.f. Required on aircraft with placarded never-exceed speed greater than 160 m.p.h.
"	MIL-C-5646	"	"	"	"	Alternate to AMS 3806.
* Airplane cloth cellulose nitrate predoped.	....	"	"	"	"	Alternate to MIL-C-5646 * or AMS 3806 (undoped). Finish with cellulose nitrate dope.
* Airplane cloth cellulose acetate butyrate, predoped.	....	"	"	"	"	Alternate to MIL-C-5646* or AMS 3806 (undoped). Finish with cellulose acetate butyrate dope.
Airplane cloth mercerized cotton.	Society Automotive Engineers AMS 3804 (TSO-C14 references this spec.).	65 pounds per inch warp and fill.	4 pounds warp and fill.	46 pounds per inch.	80 min., 94 max. warp and fill.	For use on aircraft with wing loadings of 9 p.s.f. or less, provided never-exceed speed is 160 m.p.h. or less.
Airplane cloth mercerized cotton.	Society Automotive Engineers AMS 3802.	50 pounds per inch warp and fill.	3 pounds warp and fill.	35 pounds per inch..	110 max. warp and fill.	For use on gliders with wing loading of 8 p.s.f. or less, provided the placarded never-exceed speed is 135 m.p.h. or less.
Glider fabric cotton.	A.A.F. No. 16128. AMS 3802	55 pounds per inch warp and fill.	4 pounds warp and fill.	39 pounds per inch.	80 mini. warp and fill.	Alternate to AMS 3802-A.
Aircraft linen....	British 7F1	....	....	....	....	This material meets the minimum strength requirements of TSO-C15.

Materials	Specification	Yarn size	Minimum tensile strength	Yards per pound	Use and remarks
Reinforcing tape, cotton.	MIL-T-5661	------------	150 pounds per one-half-inch width.	------------	Used as reinforcing tape on fabric and under rib lacing cord. Strength of other widths approx. in proportion.
Lacing cord, pre-waxed braided cotton.	MIL-C-5649	------------	80 pounds double.	310 minimum.	Lacing fabric to structures. Unless already waxed, must be lightly waxed before using.
Lacing cord, special cotton.	U.S. Army No. 6-27.	20/3/3/3	85 pounds double.	------------	"
Lacing cord, braided cotton.	MIL-C-5648	------------	80 pounds single.	170 minimum.	"
Lacing cord thread; linen and linen-hemp.	MIL-T-6779	9 ply 11 ply	59 pounds single. 70 pounds single.	620 minimum. 510 minimum.	"
Lacing cord thread; high-tenacity cotton.	MIL-T-5660	Ticket No. 10.	62 pounds single.	480 minimum.	"
Machine thread cotton.	Federal V-T-276b.	20/4 ply	5 pounds single.	5,000 normal.	Use for all machine sewing.
Hand sewing thread cotton.	V-T-276b. Type III B.	8/4 ply	14 pounds single.	1,650 normal.	Use for all hand sewing. Use fully waxed thread.
Surface tape cotton (made from AN-C-121).	MIL-T-5083	------------	80 lbs/in.	------------	Use over seams, leading edges, trailing edges, outer edges and ribs, pinked, scalloped or straight edges.
Surface tape cotton.	Same as fabric used.	------------	Same as fabric used.	------------	Alternate to MIL-T-5083.

FIGURE 3.2.—Miscellaneous textile materials.

b. ***Doped Seams.***

(1) For a lapped and doped spanwise seam on a metal- or wood-covered leading edge, lap the fabric at least 4 inches and cover with pinked-edge surface tape at least 4 inches wide.

(2) For a lapped and doped spanwise seam at the trailing edge, lap the fabric at least 4 inches and cover with pinked-edge surface tape at least 3 inches wide.

131. COVERING METHODS.

a. ***The Envelope Method.*** The envelope method of covering is accomplished by sewing together widths of fabric cut to specified dimensions and machine sewn to form an envelope which type shown in figure 3.4). The spacing between the starting stitch and the next stitch should be one-half the normal stitch spacing. Final location of the knot depends upon the original location selected by the manufacturer. If such information is not available, consider positioning the knot where it will have the least effect on the aerodynamics of the airfoil. The seine knot admits a possibility of improper tightening, resulting in a false (slip) form with greatly reduced efficiency and must not be used for stitch tie-offs. Lock the tie-off knot for the last stitch by an additional half-hitch. Where stitching ends, as at the rear beam and at the trailing edge, space the last two stitches at one-half normal spacing. Under no circumstances pull tie-off knots back through the lacing holes.

b. *The double-loop lacing* illustrated in figure 3.7 represents a method for obtaining higher strengths than possible with the standard single lacing. When using the double-loop lacing, use the tie-off knot shown in figure 3.8.

c. *Fuselage Lacing.* Fabric lacing is also necessary in the case of deep fuselages, and on fuselages where former strips and ribs shape the fabric to a curvature. In the latter case, lace the fabric at intervals to the formers. Attachment of the fabric to fuselages must be so accomplished as to be at least the equivalent in strength and reliability to that used by the manufacturer of the airplane.

* **d. *Blind Stitch Lacing.*** Thick airfoil sections, and those places on an aircraft where a conventional stitch cannot be used to secure fabric, require blind stitch lacing.

A 4- to 6-inch curved needle and standard rib lacing card are used. Lay out stitch pattern according to manufacturer's instructions. Follow the step-by-step instructions given in figure 3.9. *

134. STITCH SPACING. The stitch spacing should not exceed the spacing approved on the original
* aircraft. In case the spacing cannot be ascertained due to destruction of the covering, acceptable rib-stitch spacing is specified in figure 3.10. Place the *
lacing holes as near to the capstrip as possible in order to minimize the tendency of the cord to tear the fabric. Lightly wax all lacing cords with

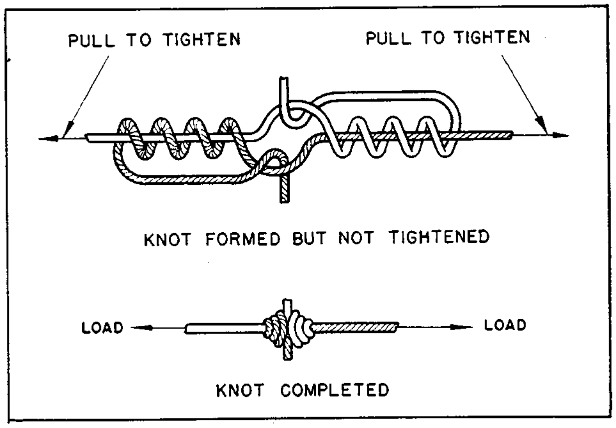

FIGURE 3.5.—Splice knot.

beeswax for protection. In case waxed-braided cord is used, this procedure is unnecessary. (See figure 3.2 for acceptable lacing cords.)

135. SURFACE TAPE (FINISHING TAPE). Cover all lacing with tape of at least the quality and width used on the original airplane. This tape should not be applied until the first coat of dope has dried. Replace all inspection openings in the covering, and reinforce the fabric around them and along leading edges with tape. Wear or friction, induced by moving parts or fittings, can be repaired by sewing a leather patch on a fabric patch and doping in place. Pinked surface tape is sometimes applied over the trailing edges of control surfaces
* and airfoils. For such applications, the tape should be at least 3 inches in width and should be notched along both edges at intervals not exceeding 6 inches. If separation of the tape from the trailing *
edge begins, it will tear at a notched section and thereby prevent loosening of the entire strip which could seriously affect the controllability of the aircraft.

136. SPECIAL FASTENERS. When repairs are made to fabric surfaces attached by special mechanical methods, duplicate the original type of fastener. When self-tapping screws are used for the attachment of fabric to the rib structure, observe the following procedure:

a. *Redrill the holes where necessary* due to wear, distortion, etc., and in such cases, use a screw one size larger as a replacement.

* **b. *Extend the length of the screw*** beyond the rib capstrip at least two threads of the grip (threaded part).

c. *Install a thin washer,* preferably celluloid, under the heads of screws and dope pinked-edge tape over each screw head. *

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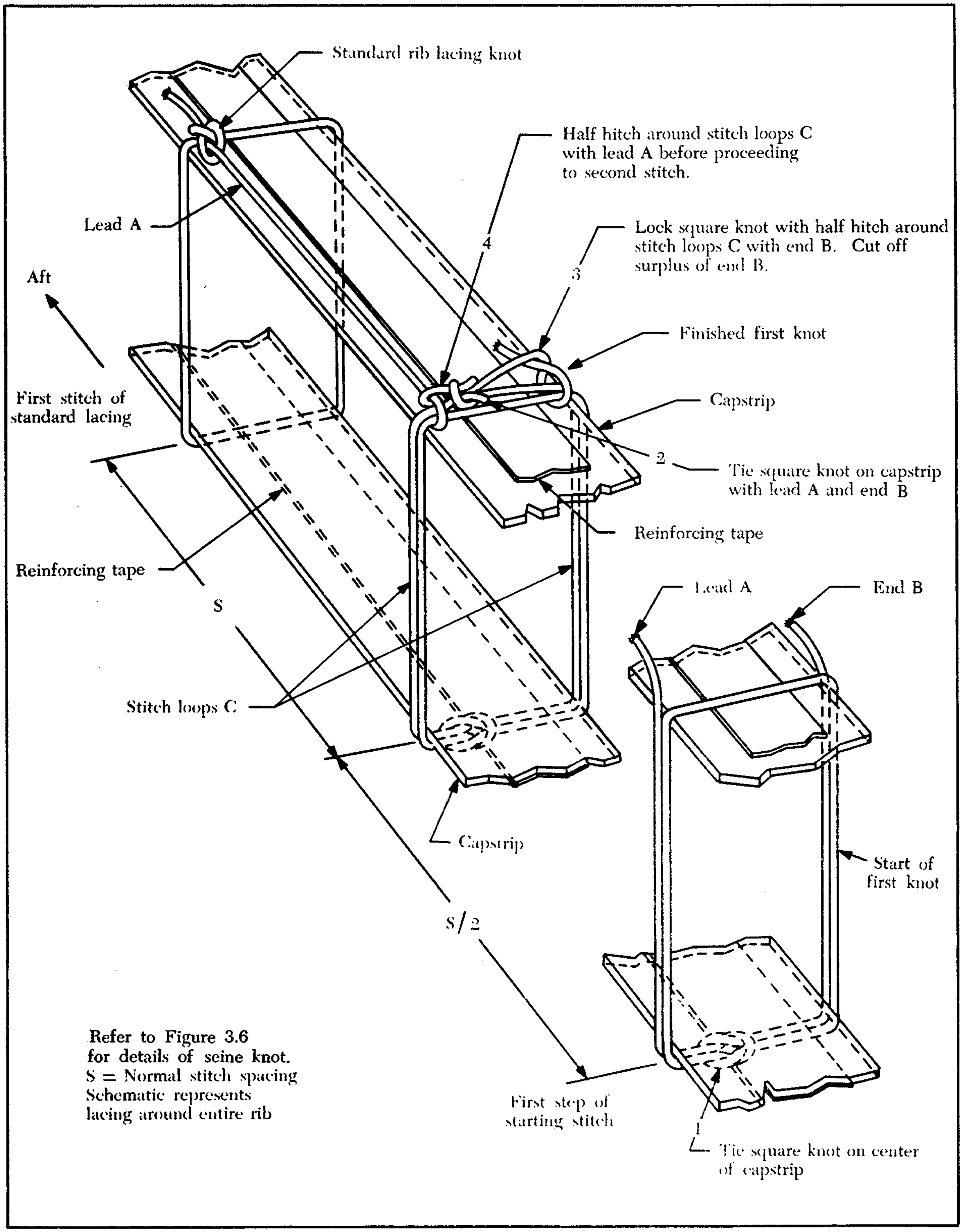

FIGURE 3.6.—Standard single loop lacing.

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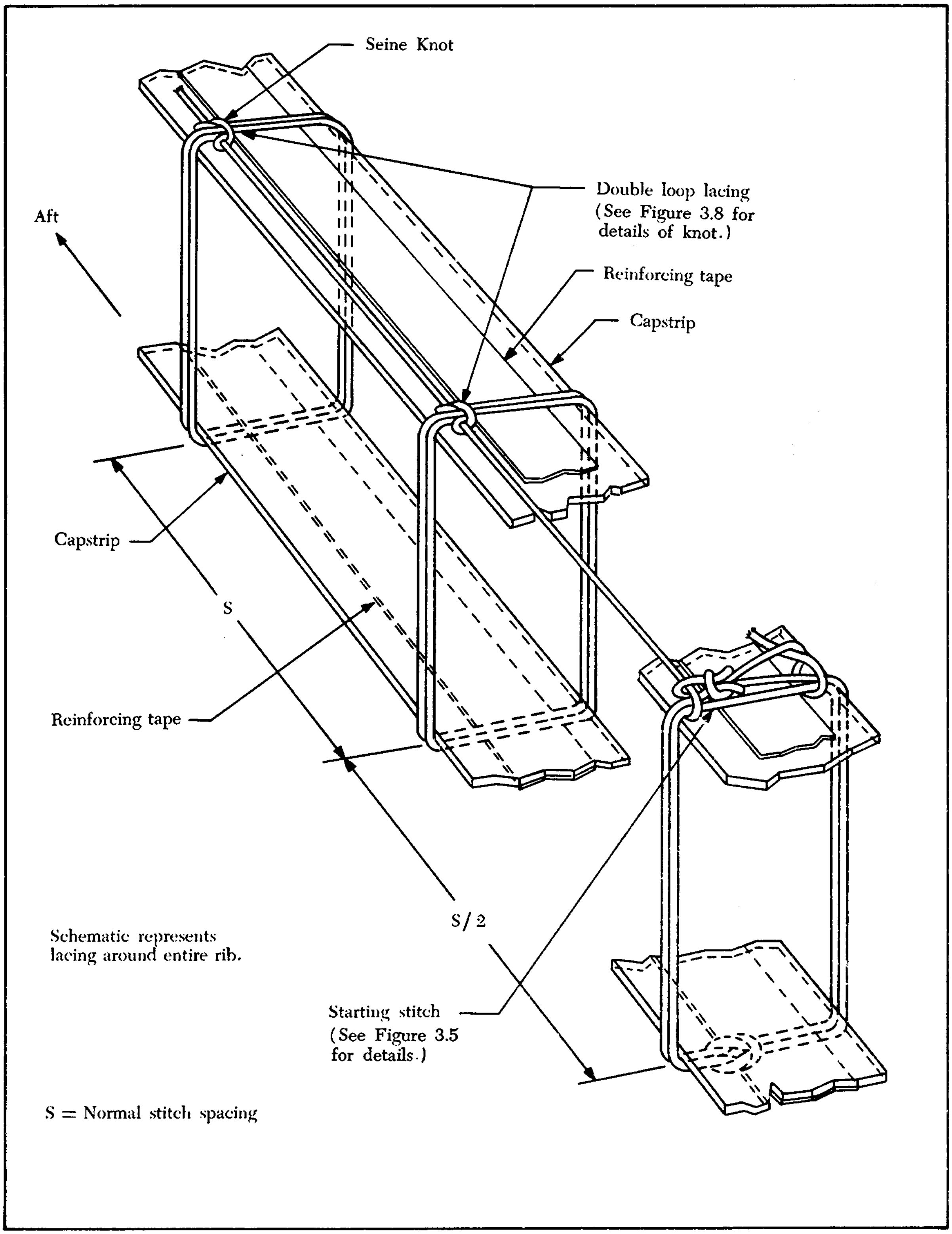

FIGURE 3.7.—Standard double loop lacing.

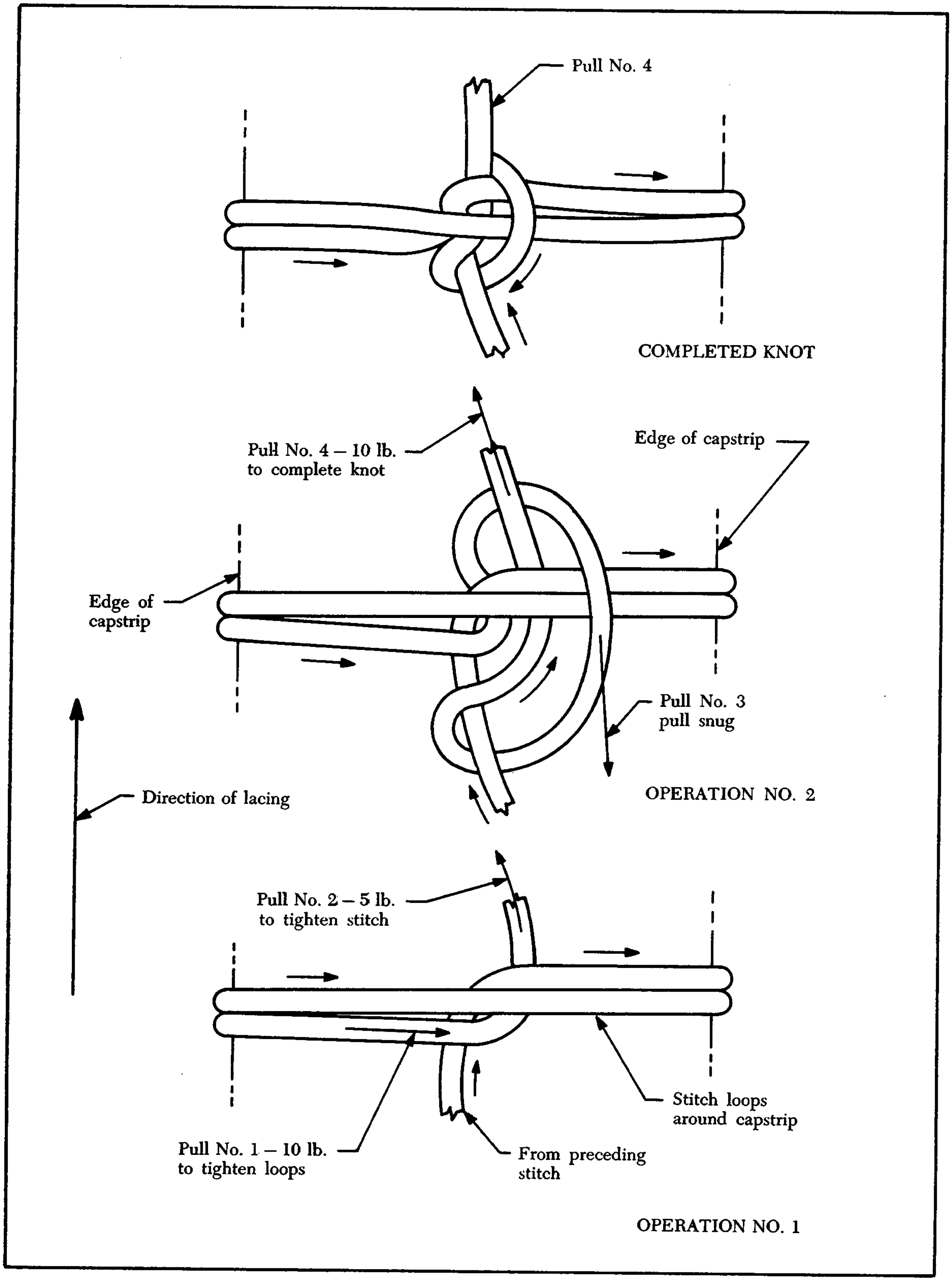

FIGURE 3.8.—Standard knot for double loop lacing.

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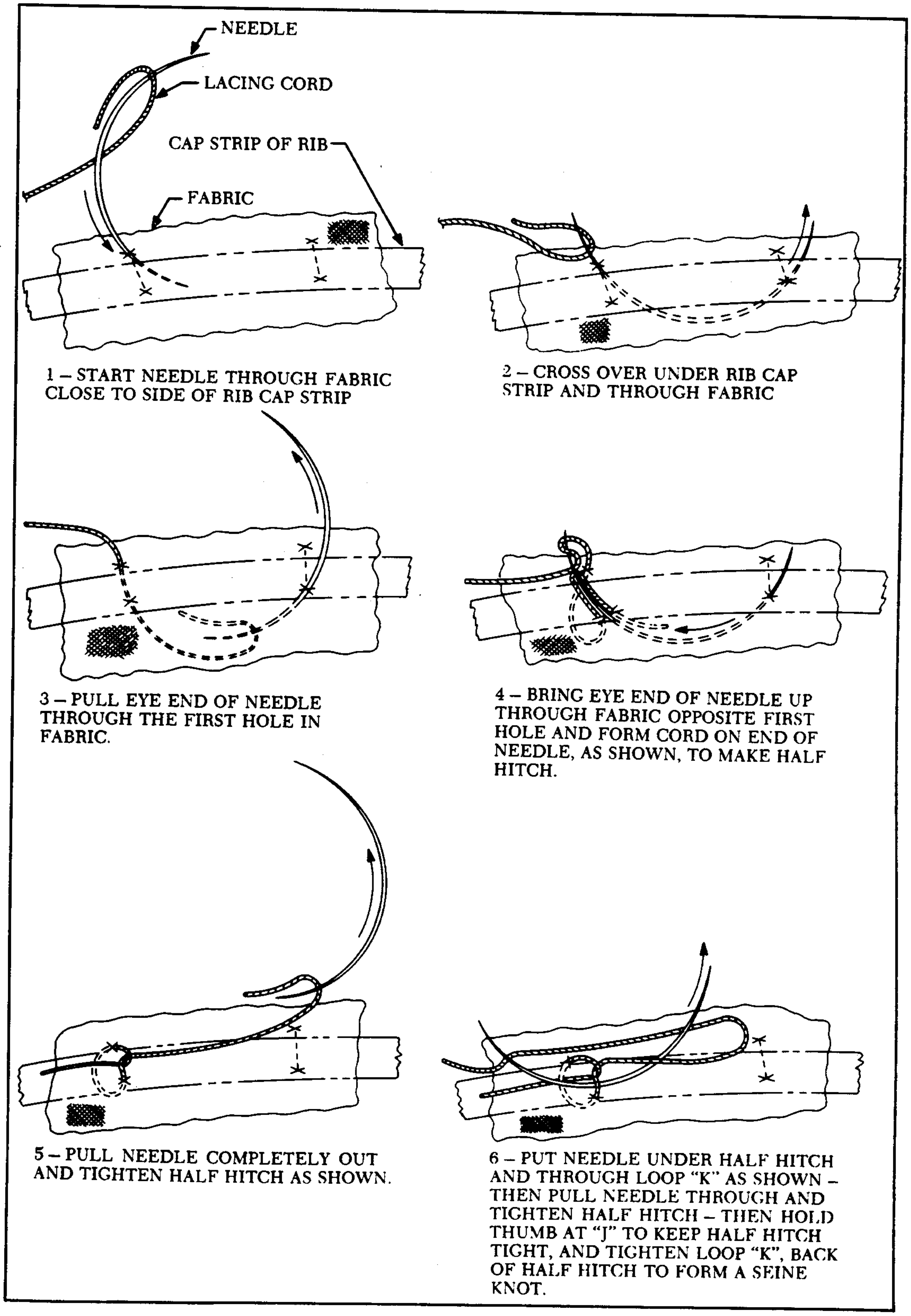

FIGURE 3.9.—Blind stitch lacing. *

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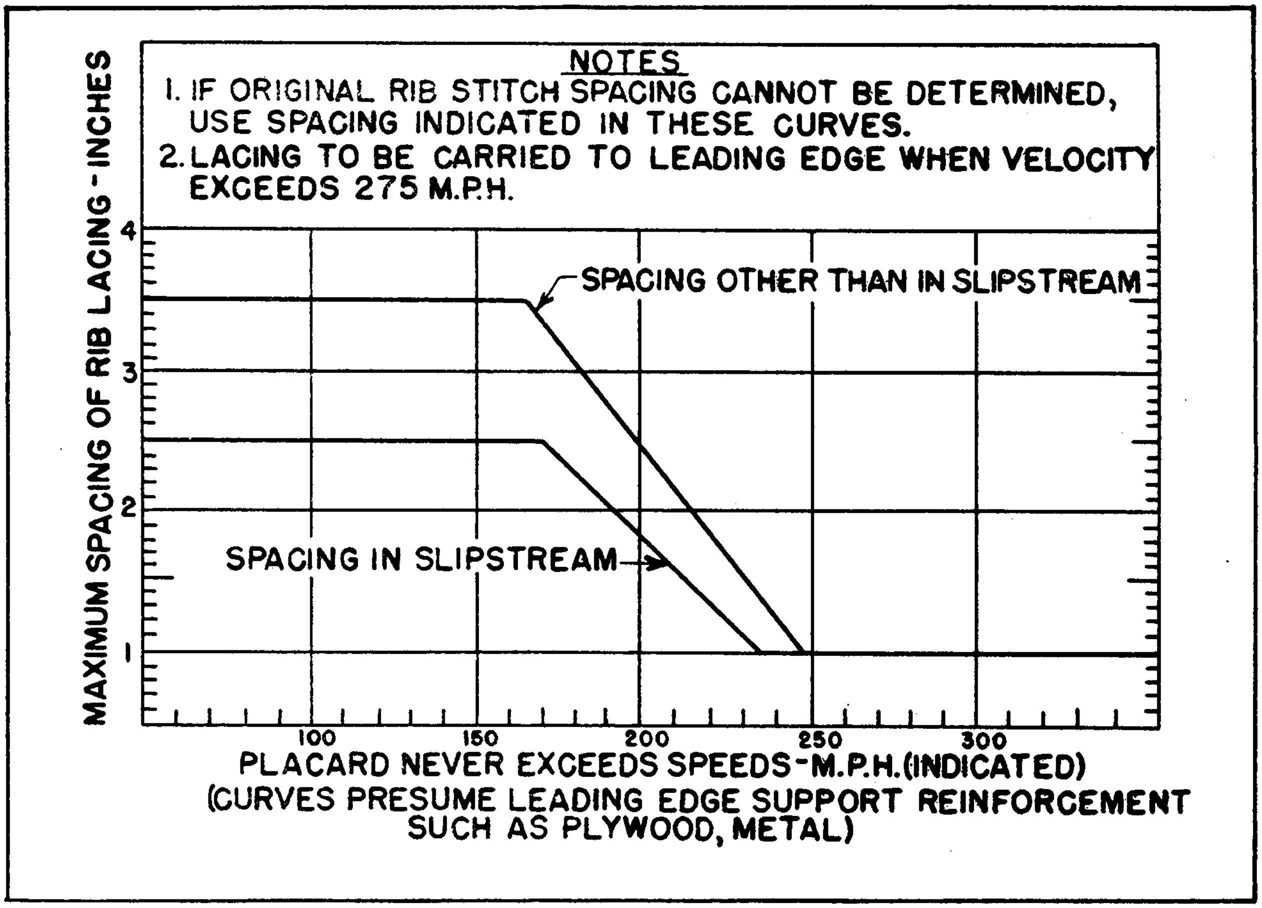


* FIGURE 3.10.—Fabric attachment spacing. *

137.-147. RESERVED.

Section 2. DOPING

148. APPLICATION OF AIRCRAFT DOPE, EPOXY, AND RESINS. Determine that dope and fabric materials are compatible by consulting the product manufacturer's instructions before applying finish to aircraft surfaces. Compatibility of products may also be determined by wetting samples of the fabric with the impregnating materials and thorough examination of the material after it has dried. The following military specifications, or later revisions thereof, apply to aircraft dope, epoxy, and polyester resins:

* FIGURE 3.11.—Military specifications for aircraft fabric finishes. *

MIL-D-5549A-1	Clear dope, cellulose-acetate butyrate.
MIL-D-7850	Fungicidal dope, first coat, cellulose-acetate, butyrate.
MIL-D-5550A-1	Pigmented dope, cellulose-acetate, butyrate.
MIL-D-5551A-2	Pigmented dope, gloss, cellulose-acetate butyrate.
MIL-D-5553A-2	Clear dope, nitrate.
MIL-D-5552A-1	Clear dope, gloss, cellulose nitrate.
MIL-D-5554A-1	Clear dope, cellulose nitrate.
MIL-D-5555-1	Pigmented dope, cellulose nitrate.
MIL-R-9300A	Resin, epoxy, low pressure laminating.
MIL-R-25042A	Resin, polyester, low pressure laminating.
MIL-R-7575B	Resin, polyester, low pressure laminating.

a. *Thinning.* Finishing materials are generally supplied at a consistency ready for brush application. For spraying operations, practically all aircraft dope, epoxy, or resin requires thinning. Thinning instructions are usually listed on the container label. Avoid use of thinning agents other than those specified by the product manufacturer. To do so may result in adverse chemical action. The amount of thinner to be used will depend on the material, atmospheric conditions, spraying equipment, the spraying technique of the operator, and the type of thinning agent employed. Thinning influences the drying time and the tautening properties of the finish, and it is necessary that it be done properly. Since local atmospheric conditions affect the doping process, determine the amount of the thinner necessary at the time the finishing material is to be applied by first using it on experimental panels.

149. BLUSHING AND USE OF BLUSH-RETARDING THINNER. Blushing of dopes is very common when doping is accomplished under humid conditions. The condition is caused by the rapid evaporation of thinners and solvents, which lowers the temperature on the surface, causing condensation of moisture and producing the white appearance known as "blush." Blushing tendencies are also increased, if strong currents of air flow over the surface when applying dope or immediately thereafter.

A blushed finish has very little protective or tautening value. When the relative humidity is such that only a small amount of blushing is encountered, the condition may be eliminated by thinning the dope with a blush-retarding thinner and slightly increasing the room temperature. If it is not possible to correct humidity conditions in the dope room, suspend doping operations until more favorable atmospheric conditions prevail. The use of large amounts of blush-retarding thinner is not advisable because of the undesirable drying properties accompanying the use of this material.

150. NUMBER OF COATS. Apply as many coats of dope as are necessary to result in a taut and well-filled finish job. A guide for finishing fabric-covered aircraft follows:

a. *Two coats of clear dope*, brushed on and sanded after the second coat.

b. *One coat of clear dope*, either brushed or sprayed, and sanded.

c. *Two coats of aluminum pigmented dope*, sanded after each coat.

d. ***Three coats of pigmented dope*** (the color desired), sanded and rubbed to give a smooth glossy finish when completed.

e. ***Care should be taken*** not to sand heavily over the center portion of pinked tape and over spars in order not to damage the rib-stitching cord and fabric.

151. TECHNIQUE. Use a brush to spread the first two coats of dope uniformly on the surface. Work the dope into the fabric thoroughly, exercising care not to form an excessive film on the reverse side. The first coat should produce a thorough and uniform wetting of the fabric. To do so, work the dope with the warp and the filler threads for three or four brush strokes and stroke away any excess material to avoid piling up or dripping. Apply succeeding brush or spray coats with only sufficient brushing to spread the dope smoothly and evenly.

When doping fabric over plywood or metal-covered leading edges, make sure that an adequate bond is obtained between the fabric and the leading edge. Also, when using pre-doped fabric, use a thinned dope in order to obtain a good bond between the fabric and the leading edge.

a. ***Surface Tape and Reinforcement Patches.*** Apply surface tape and reinforcement patches with the second coat of dope. Apply surface tape over all rib lacing and over all sewed seams as well as all other points of the structure where tape reinforcements are indicated.

b. ***Installation of Drain Grommets.*** With the second coat of dope, install drain grommets on the underside of airfoils, at the center of the underside in each fuselage bay, located so that the best possible drainage is obtained. On seaplanes, installation of special shielded or marine grommets is recommended to prevent the entry of spray. Also, use this type of grommet on landplanes in that part of the structure which is subject to splash from the landing gear when operating from wet and muddy fields. Dope plastic-type grommets directly to the covering. When brass grommets are used, mount them on fabric patches and then dope them to the covering. After the dope scheme is completed, open the drainholes by cutting out the fabric with a small-bladed knife. Do not open drain-grommets by punching.

c. ***Use of Fungicidal Dope.*** Fungicidal dope is normally used as the first coat for fabrics to prevent rotting. While it may be more advisable to purchase dope in which the fungicide has already been incorporated, it is feasible to mix the fungicide with the dope.

Specification MIL-D-7850 specifies that the requirements for cellulose acetate butyrate dope incorporate a fungicide for first coat use on aircraft. The fungicide specified in this specification is zinc dimethyldithiocarbonate which forms a suspension with the dope. This material is a fine powder, and if it is mixed with the dope, it should be made into a paste-using dope, and then diluted to the proper consistency according to the manufacturer's instructions. It is not practicable to mix the powder with a large quantity of dope.

Copper napthonate is also used as a fungicide and forms a solution with dope. However this substance has a tendency to "bleed out," especially on light-colored fabric. It is considered satisfactory from a fungicidal standpoint.

Apply the first coat of fungicidal dope extremely thin so that the dope can thoroughly saturate both sides of the fabric. Once the fabric is thoroughly saturated, subsequent coats can be applied at any satisfactory working consistency.

152. REJUVENATION OF FABRIC. Before using fabric rejuvenator products to improve the appearance or condition of doped surfaces, care should be exercised to establish that the fabric strength has not deteriorated beyond safe limits. Experience has indicated that rejuvenation may at times cause fabric-sag rather than tautening. When the surface to be rejuvenated has been thoroughly cleaned and the rejuvenator applied according to the manufacturer's directions, the old dope should soften through to the fabric. Cracks may then be sealed and the surface allowed to set. Finishing coats of clear and pigmented dopes can then be applied in the normal manner.

153. COMMON DOPE TROUBLES.

a. In cold weather, dopes become quite viscous. Cold dopes pull and rope under the brush, and if thinned sufficiently to spray, lack body when dry. Prior to use, allow dopes to come to a temperature approximately that of the dope room, 24° C. (75° F.).

b. Orange peel and pebble effect result from insufficiently thinned dope or when the spray gun is held too far from the surface being sprayed.

c. Runs, sags, laps, streaks, high and low spots are caused by improperly adjusted spraying equipment or improper spraying technique.

d. Blisters may be caused by water or oil entering the spray gun. Drain air compressors, air regulators, and air lines daily.

e. Pinholes may be caused by not allowing sufficient time for drying between coats or after water sanding, or they may be due to insufficiently reduced dope.

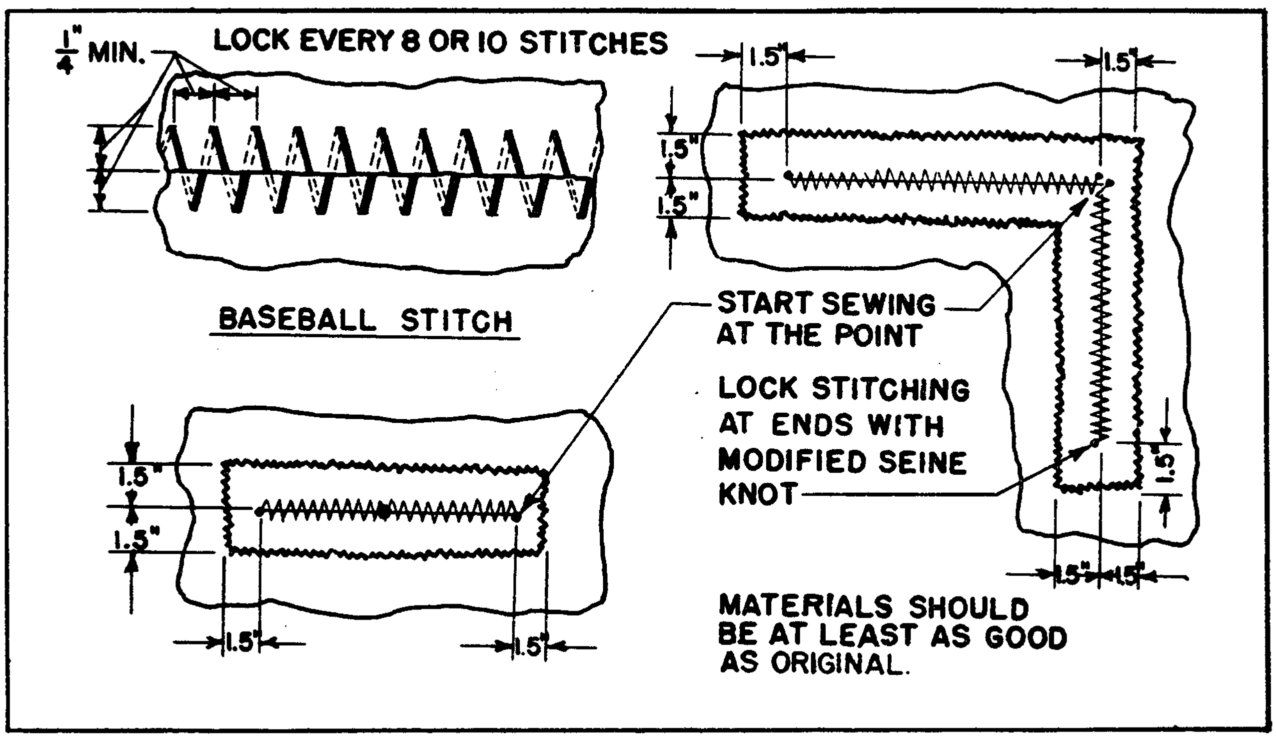
f. Wet areas on a doped surface indicate that oil, grease, soap, etc., had not been properly removed before doping.

154.-164. RESERVED.

Section 3. REPAIRS TO FABRIC COVERING

165. GENERAL. Make repairs to fabric-covered surfaces in a manner that will return the original strength and tautness to the fabric. Sewed repairs and unsewed (doped-on patches or panels) may be made. Do not dope fabric or tape onto a surface which contains aluminum or other color coats. Whenever it is necessary to add fabric reinforcement, remove the old dope either by softening and scraping, or by sanding down to the point where the base coat or clear coat is exposed. Use clear dope in doping the fabric to the surface. After reinforcement is made, normal finishing procedures may be followed.

* **166. REPAIR OF TEARS IN FABRIC.** Repair tears as shown in figure 3.12 by sewing the torn edges together using a baseball stitch and doping a piece of pinked-edge fabric over the tear. If the * tear is a straight rip, the sewing is started at one end so that, as the seam is made, the edges will be drawn tightly together throughout its entire length. If the openings are cut in wings to inspect the internal structure, start the sewing at the corner or point so that the edges of the cover will be held in place while the seams are being made. The sewing is done with a curved needle and well-waxed thread. Clean the surface to be covered by the patch by rubbing the surface with a rag dipped in dope, wiping dry with a clean rag, or by scraping the surface with a putty knife after it has been softened with fresh dope. Dope solvent or acetone may be used for the same pur-



* FIGURE 3.12.—Repair of tears in fabric. *

pose, but care should be taken that it does not drop through on the inside of the opposite surface, causing the dope to blister. Cut a patch of sufficient size from airplane cloth to cover the tear and extend at least 1 1/2 inches beyond the tear in all directions. The edges of the patch should either be pinked similar to surface tape or frayed out about 1/4 inch on all edges.

*167. **SEWED PATCH REPAIR.** When the damage is such that it will not permit sewing the edges together, a sewed-in repair patch may be used if the damage is not longer than 16 inches in any one direction (see figure 3.12). Cut out the damaged sec-* tion, making a round or oval-shaped opening trimmed to a smooth contour. Clean the area of the old fabric to be doped as indicated in paragraph 166. Turn the edges of the patch 1/2 inch and sew to the edges of the opening. Before sewing, fasten the patch at several points with a few temporary stitches to facilitate sewing the seams. After the sewing is completed, clean the area of the old fabric to be doped as indicated for small repairs and then dope the patch in the regular manner. Apply surface tape over the seam with the second coat of dope. If the opening extends over or closer than 1 inch to a rib or other laced member, extend the patch 3 inches beyond the member. After sewing has been completed, rib lace the patch to the rib over a new section of reinforcing tape, using the method explained in paragraph 133. Do not remove the old rib lacing and reinforcing tape.

168. **UNSEWED (DOPED-ON) REPAIRS.** Unsewed (doped-on) repairs may be made on all aircraft fabric-covered surfaces provided the never-exceed speed is not greater than 150 miles per hour. A doped patch repair may be used if the damage does not exceed 16 inches in any direction. Cut out the damaged section making a round or oval shaped opening, trimmed to a smooth contour. Clean the edges of the opening which are to be covered by the patch with a grease solvent. Sand or wash off the dope from the area around the patch with dope thinner. Support the fabric from underneath while sanding.

For holes up to 8 inches in size, make the fabric patch of sufficient size to provide a lap of at least 2 inches around the hole. On holes over 8 inches in size, make the overlap of the fabric around the hole at least 1/4 the hole diameter with a maximum limit of lap of 4 inches. If the hole extends over a rib or closer than the required overlap to a rib or other laced member, extend the patch at least 3 inches beyond the rib. In this case, after the edges of the patch have been doped in place and the dope has dried, lace the patch to the rib over a new section of reinforcing tape in the usual manner. Do not remove the old rib lacing and reinforcing tape. All patches should have pinked edges or, if smooth, should be finished with pinked-edge surface tape.

169. **REPAIR BY A DOPED-IN PANEL.** When the damage exceeds 16 inches in any direction, make the repair by doping in a new panel. This type of repair may be extended to cover both the upper and lower surfaces and to cover several rib bays if necessary. Lace the panel to all the ribs covered, and dope or sew as in the blanket method.

a. ***Remove the surface tape*** from the ribs adjacent to the damaged area and from the trailing and leading edges of the section being repaired. Leave the old reinforcing tape and lacing in place. Next, cut the fabric along a line approximately 1 inch from the ribs on the sides nearest the injury and continue the cuts to completely remove the damaged section. Do not remove the old fabric from the leading and trailing edges, unless both upper and lower surfaces are being re-covered.

b. ***Cut a patch*** to run around the trailing edge 1 inch and to extend from the trailing edge up to and around the leading edge and back approximately to the front beam. Extend the patch approximately 3 inches beyond the ribs adjacent to the damage.

As an alternative attachment on metal- or wood-covered leading edges, the patch may be lapped over the old fabric at least 4 inches at the nose of the leading edge, doped, and finished with at least 4 inches of pinked-edge surface tape.

c. ***Clean the area of the old fabric*** that is to be covered by the patch and apply a generous coat of dope to this area. Put the new panel in place, pull as taut as possible, and apply a coat of dope to that portion of the panel which overlaps the old fabric. After this coat has dried, apply a second coat of dope to the overlapped area and let dry.

d. ***Place reinforcing tape over the ribs*** under moderate tension and lace down in the approved manner.

e. ***Give the panel a coat of clear dope*** and allow to dry. Install surface tape with the second coat of dope over the reinforcing tape and over the edges of the panel. Finish the dope scheme, using the regular doping procedure.

170.-180. RESERVED.

Section 4. FABRIC TESTING

181. TESTING OF FABRIC COVERING. Field test instruments that are commonly used to test the tensile strength of aircraft fabric covering give only approximate indications of the fabric condition. Since the accuracy of field test instruments is affected by climatic and environmental conditions, a laboratory test is recommended when aircraft fabric covering is found to be marginal by field test methods. Laboratory test procedures are set forth in Federal Specification CCC-T-191B, methods 5122, 5132, 5134, or 5136; American Society of Testing Materials (ASTM) Method D39-61 or D39-49, and others. In all cases, test fabric specimens in the undoped condition. Use acetone, dope thinner, or other appropriate thinning agents for the removal of finishing materials.

a. *Strength Criteria for Aircraft Fabric.*

(1) Present minimum strength values for new aircraft fabric covering are contained in figure 3.1.

(2) The maximum permissible deterioration for used aircraft fabric based on a large number of tests is 30 percent. Fabric which has less than 70 percent of the original required tensile strength would not be considered airworthy. Figure 3.1 contains the minimum tensile strength values for deteriorated fabric as tested in the undoped condition.

(3) Grade A fabric may be used where only intermediate fabric is required. When testing for deteriorated condition, 46 pounds (70 percent of original requirements for intermediate fabric) is considered airworthy.

(4) Failures may occur in fiberglass covering where rib stitching has worn through the reinforcing tape and covering material without being detected through visual inspection. Such failures can be located by using a suitable suction cup and lifting the fabric in the rib stitched area. If the fabric pulls away from the ribs, new stitching will need to be applied using additional reinforcing tape and doubling the number of stitches throughout the affected area. Give particular attention to the areas within the propeller slipstream area.

182.-192. RESERVED.

Chapter 4. CONTROL CABLES AND TERMINALS

Section 1. INSPECTION AND REPAIR

193. GENERAL. Aircraft control cables are generally fabricated from carbon steel or corrosion-resistant steel wire and may consist of either flexible or nonflexible type construction.

Contents of this section may be used for control cable installations pertaining to both primary and secondary system applications.

a. *Cable Definitions*. Construction features of various cables are shown in figure 4.1. The following terms define components used in aircraft control cables.

(1) Wire—Each individual cylindrical steel rod or thread.

(2) Strand—Each group of wires helically twisted or laid.

(3) Core Strand—The central strand about which the remaining strands of the cable are helically laid.

(4) Cable—A group of strands helically twisted or laid about a central core.

(5) Preformed Cable—Cable in which the wires and strands are shaped prior to fabrication of the cable.

(6) Diameter—The diameter of cable is the diameter of the circumscribed circle.

(7) Lay or Twist—The helical form taken by the wires and strands in a cable. A cable is said to have a right-hand lay if the wires and strands twist in the same direction as the thread on a right-hand screw.

(8) Pitch—The distance in which a strand or wire makes one complete revolution about the axis of the cable or strand respectively.

194. CABLE SPECIFICATIONS. Cable size and strength data are given in figure 4.2. These values are acceptable for repair and modification of civil aircraft.

a. *Cable Proof Loads*. Cable terminals and splices should be tested for proper strength prior to installation. Gradually apply a test load equal to 60 percent of the cable breaking strengths given in figure 4.2 for a period of 3 minutes. Place a suitable guard over the cable during the test to prevent injury to personnel in the event of cable failure.

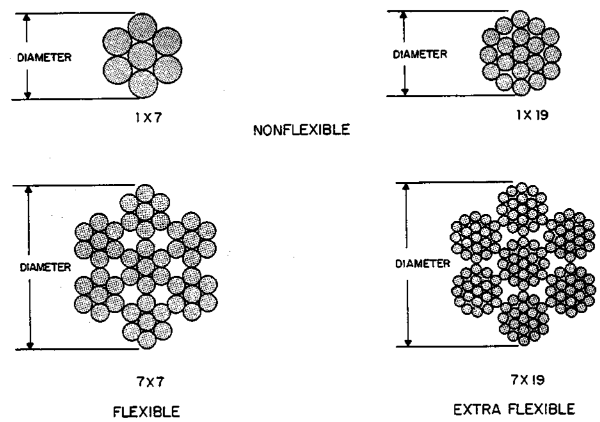


FIGURE 4.1.—Cable cross section.

195. REPLACEMENT OF CABLES. Replace control cables when they become worn, distorted, corroded, or otherwise injured. If spare cables are not available, prepare exact duplicates of the damaged cable. Use materials of the same size and quality as the original. Standard swaged cable terminals develop the full cable strength and may be substituted for the original terminals wherever practical. However, if facilities and supplies are limited and immediate corrective action is necessary, repairs may be made by using cable bushings, eye splices, and the proper combination of turnbuckles in place of the original installation. (See figure 4.6c.)

a. *Location of Splices*. Locate splices so that no portion of the splice comes closer than two

FIGURE 4.2.—Strength of steel cable.

* Diameter (inch)	1 x 7 and 1 x 19				7 x 7, 7 x 19, and 6 x 19 (1WRC)				*
	Nonflexible, carbon		Corrosion resisting		Flexible, carbon		Flexible, corrosion resisting		
	MIL-W-6940		MIL-W-5693		MIL-W-1511		MIL-C-5424		
	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds	
1/32	0.25	185	0.25	150					
3/64	.55	375	.55	375					
1/16	.85	500	.85	500	0.75	480	0.75	480	
5/64	1.40	800	1.40	800					
3/32	2.00	1,200	2.00	1,200	1.60	920	1.60	920	
7/64	2.70	1,600	2.70	1,600					
1/8	3.50	2,100	3.50	2,100	2.90	2,000	2.90	1,760	
5/32	5.50	3,300	5.50	3,300	4.50	2,800	4.50	2,400	
3/16	7.70	4,700	7.70	4,700	6.50	4,200	6.50	3,700	
7/32	10.20	6,300	10.20	6,300	8.60	5,600	8.60	5,000	
1/4	13.50	8,200	13.50	8,200	11.00	7,000	11.00	6,400	
9/32					13.90	8,000	13.90	7,800	
5/16	21.00	12,500	21.00	12,500	17.30	9,800	17.30	9,000	
11/32					20.70	12,500			
3/8					24.30	14,400	24.30	12,000	
7/16					35.60	17,600	35.60	16,300	
1/2					45.80	22,800	45.80	22,800	

*The strength values listed were obtained from straight tension tests and do not include the effects of wrapped ends.

inches to any fair-lead or pulley. Locate connections at points where jamming cannot occur during any portion of the travel of either the loaded cable or the slack cable in the deflected position.

b. *Cutting and Heating.* Cut cables to length by mechanical means. The use of a torch in any manner is not permitted. Do not subject wires and cables to excessive temperature. Soldering bonding braid to control cable will not be considered satisfactory.

c. *Ball-and-Socket Type Terminals.* Do not use ball-and-socket type terminals or other types for general replacement that do not positively prevent cable untwisting, except where they were utilized on the original installation by the aircraft manufacturer.

d. *Substitution of Cable.* Substitution of cable for hard or streamlined wires will not be acceptable unless specifically approved by a representative of the Federal Aviation Administration.

196. MECHANICALLY FABRICATED CABLE ASSEMBLIES.

a. *Swage Type Terminals.* Swage type terminals, manufactured in accordance with Air Force-Navy Aeronautical Standard Specifications, are suitable for use in civil aircraft up to and including maximum cable loads. When swaging tools are used, it is important that all the manufacturers' instructions, including "go and no-go" dimensions, be followed in detail to avoid defective and inferior swaging. Observance of all instructions should result in a terminal developing the full rated strength of the cable. Critical dimensions, both before and after swaging, are shown in figure 4.3.

(1) Terminals. When swaging terminals onto cable ends, observe the following procedure:

(a) Cut the cable to the proper length, allowing for growth during swaging. Apply a preservative compound to the cable ends before insertion into the terminal barrel.

* FIGURE 4.3.—Straight-shank terminal dimensions (cross reference AN to MS: AN-666 to MS 21259, AN-667 to MS 20667, AN-668 to MS 20668, AN-669 to MS 21260) *

Cable size (inches)	Wire strands	Before swaging				After swaging	
		Outside diameter	Bore diameter	Bore length	Swaging length	Minimum breaking strength (pounds)	Shank diameter*
1/16	7 x 7	0.160	0.078	1.042	0.969	480	0.138
3/32	7 x 7	.218	.109	1.261	1.188	920	.190
1/8	7 x 19	.250	.141	1.511	1.438	2,000	.219
5/32	7 x 19	.297	.172	1.761	1.688	2,800	.250
3/16	7 x 19	.359	.203	2.011	1.938	4,200	.313
7/32	7 x 19	.427	.234	2.261	2.188	5,600	.375
1/4	7 x 19	.494	.265	2.511	2.438	7,000	.438
9/32	7 x 19	.563	.297	2.761	2.688	8,000	.500
5/16	7 x 19	.635	.328	3.011	2.938	9,800	.563
3/8	7 x 19	.703	.390	3.510	3.438	14,400	.625

*Use gauges in kit for checking diameters.

NOTE: Never solder cable ends to prevent fraying since the presence of the solder will greatly increase the tendency of the cable to pull out of the terminal.

(b) Insert the cable into the terminal approximately 1 inch, and bend toward the terminal; straighten the cable back to normal position and then push the cable end entirely into the terminal barrel. The bending action puts a kink or bend in the cable end and provides enough friction to hold the terminal in place until the swaging operation can be performed. Bending also tends to separate the strands inside the barrel, thereby reducing the strain on them.

NOTE: If the terminal is drilled completely through, push the cable into the terminal until it reaches the approximate position shown in figure 4.4. If the hole is not drilled through, insert the cable until the end rests against the bottom of the hole.

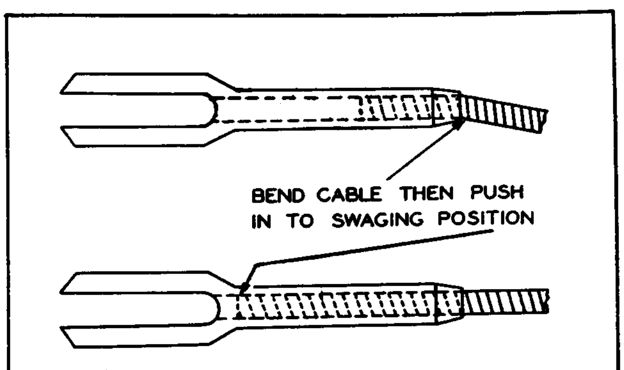


FIGURE 4.4.—Insertion of cable into terminal.

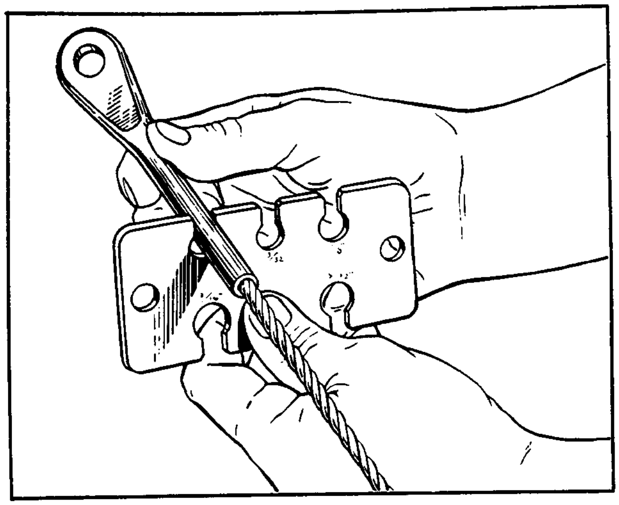


FIGURE 4.5.—Gauging terminal shank after swaging.

(c) Accomplish the swaging operation in accordance with the instructions furnished by the manufacturer of the swaging equipment.

(d) Inspect the terminal after swaging to determine that it is free from die marks and splits, and is not out-of-round. Check for cable slippage in the terminal and for cut or broken wire strands.

(e) Using a "go no-go" gauge or a micrometer, check the terminal barrel diameter as shown in figure 4.5.

(f) Test the cable by proof-loading it to 60 percent of its rated breaking strength.

(2) Splicing. Completely severed cables, or those badly damaged in a localized area, may be repaired by the use of an eye terminal bolted to a clevis terminal. (See figure 4.6a.) However, this type of splice can only be used in free lengths of cable which do not pass over pulleys or through fair-leads.

(3) Swaged Ball Terminals. On some aircraft cables, swaged ball terminals are used for attaching cables to quadrants and special connections where space is limited. Single shank terminals are generally used at the cable ends, and double shank fittings may be used at either the end or in the center of the cable. Dies are supplied with the swaging machines for attaching these terminals to cables in the following manner:

(a) The steel balls and shanks have a hole through the center, and are slipped over the cable and positioned in the desired location.

(b) Perform the swaging operation in accordance with the instructions furnished by the manufacturer of the swaging equipment.

(c) Check the swaged fitting with a "go no-go" gauge to see that the fitting is properly compressed. (See figure 4.7.) Also inspect the physical condition of the finished terminal.

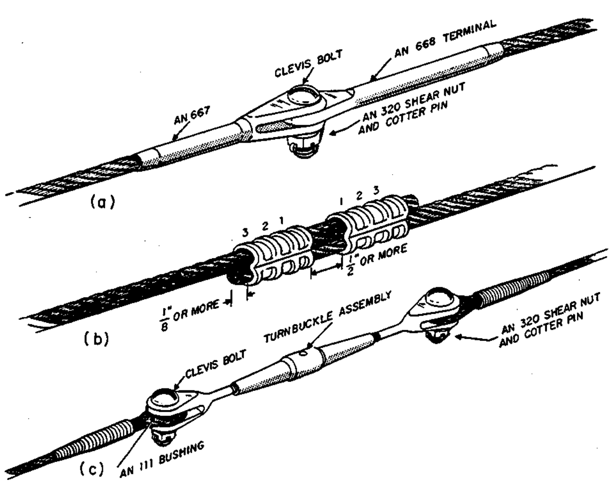


FIGURE 4.6.—Typical cable splices.

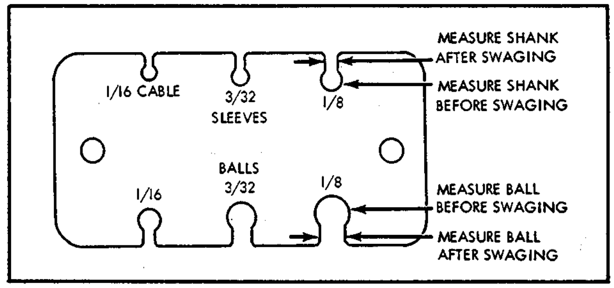


FIGURE 4.7.—Typical terminal gauge.

(4) Cable Slippage in Terminal. Ensure that the cable is properly inserted in the terminal after the swaging operation is completed. Instances have been noted wherein only 1/4 inch of the cable was swaged in the terminal. Observance of the following precautions should minimize this possibility:

(a) Measure the length of the terminal end of the fitting to determine the proper length of cable to be inserted into the barrel of the fitting.

(b) Lay off this length at the end of the cable and mark with masking tape. Since the tape will not slip, it will provide a positive marking during the swaging process.

(c) After swaging, check the tape marker to make certain that the cable did not slip during the swaging operation.

(d) Remove the tape and, using red paint, paint the junction of the swaged fitting and cable.

(e) At all subsequent service inspections of the swaged fittings, check for a gap in the painted section to see if cable slippage has occurred.

b. *Nicopress Process.* A patented process using copper sleeves may be used up to the full rated strength of the cable when the cable is looped around a thimble. This process may also be used in place of the five-tuck splice on cables up to and including 3/8-inch diameter. The use of sleeves that are fabricated of materials other than copper will require engineering approval of the specific application by a representative of the Federal Aviation Administration.

FIGURE 4.8.—Copper oval sleeve data.

Cable size	Copper oval sleeve stock No.		Manual tool No.	Sleeve length before compression (approx.) (inches)	Sleeve length after compression (approx.) (inches)	Number of presses	Tested strength (pounds)
	Plain	Plated*					
3/34	18-11-B4	28-11-B4	51-B4-887	3/8	7/16	1	340
1/16	18-1-C	28-1-C	51-C-887	3/8	7/16	1	550
3/32	18-2-G	28-2-G	51-G-887	7/16	1/2	1	1,180
1/8	18-3-M	28-3-M	51-M-850	9/16	3/4	3	2,300
5/32	18-4-P	28-4-P	51-P-850	5/8	7/8	3	3,050
3/16	18-6-X	28-6-X	51-X-850	1	1 1/4	4	4,350
7/32	18-8-F2	28-8-F2	51-F2-850	7/8	1 1/16	4	5,790
1/4	18-10-F6	28-10-F6	3-F6-950	1 1/8	1 1/2	3	7,180
5/16	18-13-G9	28-13-G9	3-G9-950	1 1/4	1 5/8	3	11,130
			No. 635 Hydraulic tool dies				
3/8	18-23-H5	28-23-H5	Oval H5	1 1/2	1 7/8	1	16,800
7/16	18-24-J8	28-24-J8	Oval J8	1 3/4	2 1/8	2	19,700
1/2	18-25-K8	28-25-K8	Oval K8	1 7/8	2 1/2	2	25,200
9/16	18-27-M1	28-27-M1	Oval M1	2	2 5/8	3	31,025
5/8	18-28-N5	28-28-N5	Oval N5	2 3/8	3 1/8	3	39,200

* *Required on stainless cables due to electrolysis caused by different types of metals. *

Before undertaking a nicopress splice, determine the proper tool and sleeve for the cable to be used. Refer to figures 4.8 and 4.10 for details on sleeves, tools, and the number of presses required for the various sizes of aircraft cable. The tool must be in good working condition and properly adjusted to assure a satisfactory splice.

To compress a sleeve, have it well centered in the tool groove with the major axis of the sleeve at right angles to the tool. If the sleeve appears to be out of line after the press is started, open the tool, re-center the sleeve, and complete the press.

(1) Thimble-Eye Splice. Initially position the cable so that the end will extend slightly beyond the sleeve, as the sleeve will elongate somewhat when it is compressed. If the cable end is inside the sleeve, the splice may not hold the full strength of the cable. It is desirable that the oval sleeve be placed in close proximity to the thimble points, so that when compressed the sleeve will contact the thimble as shown in figure 4.9. The sharp ends of the thimble may be cut off before being used; however, make certain the thimble is firmly secured in the cable loop after the splice has been completed. When using a sleeve requiring three compressions, make the center compression first, the compression next to the thimble second, and the one farthest from the thimble last.

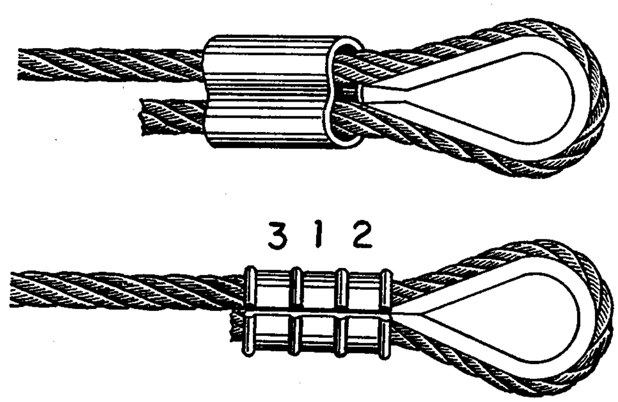


FIGURE 4.9.—Typical thimble-eye splice.

(2) Lap Splice. Lap or running splices may also be made with copper oval sleeves. When making such splices, it is usually necessary to use two sleeves to develop the full strength of the cable. The sleeves should be positioned as shown in figure 4.6b, and the compressions made in the order shown. As in the case of eye splices, it is desirable to have the cable ends extend beyond the sleeves sufficiently to allow for the increased length of the compressed sleeves.

(3) Stop Sleeves. Stop sleeves may be used for special cable end and intermediate fittings and they are installed in the same manner as Nicopress oval sleeves.

NOTE: All stop sleeves are plain copper—certain sizes are colored for identification.

(4) Terminal Gauge. To make a satisfactory copper sleeve installation, it is important that the amount of sleeve pressure be kept uniform. The completed sleeves should be checked periodically with the proper gauge. Hold the gauge so that it contacts the major axis of the sleeve. The compressed portion at the center of the sleeve should enter the gauge opening with very little clearance, as shown in figure 4.11. If it does not, the tool must be adjusted accordingly.

(5) Other Applications. The preceding information regarding copper oval sleeves and stop sleeves is based on tests made with flexible aircraft cable. The sleeves may also be used on wire ropes of other constructon if each specific type of cable is proof tested initially. Because of variation in rope strengths, grades, construction, and actual diameters, the test is necessary to insure proper selection of materials, the correct pressing procedure, and an adequate margin of safety for the intended use.

Cable size (inch)	Sleeve No.	Tool No.	Sleeve length (inch)	Sleeve O.D. (inch)	Tested strength (pounds
3/64	871-12-B4	51-B4-887	7/32	11/64	280
1/16	871-1-C	51-C-887	7/32	13/64	525
3/32	871-17-J (Yellow)	51-MJ	5/16	21/64	600
1/8	871-18-J (Red)	51-MJ	5/16	21/64	800
5/32	871-19-M	51-MJ	5/16	27/64	1, 200
3/16	871-20-M (Black)	51-MJ	5/16	27/64	1, 600
7/32	871-22-M	51-MJ	5/8	7/16	2, 300
1/4	871-23-F6	3-F6-950	11/16	21/32	3, 500
5/16	871-26-F6	3-F6-950	11/16	21/32	3, 800

NOTE: All stop sleeves are plain copper—certain sizes are colored for identification.

FIGURE 4.10.—Copper stop sleeve data.

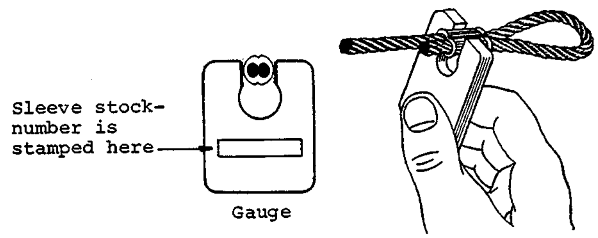


FIGURE 4.11.—Typical terminal gauge.

197. HAND FABRICATED CABLE ASSEMBLIES.

a. Woven Splice Terminal. The 5-tuck woven splice may be utilized on 7×7 flexible and 7 ×19 extra-flexible cables of 3/32 inch diameter or greater; however, this type of terminal will only develop 75 percent of the cable strength. It should not be used to replace high efficiency terminals unless it is definitely determined the design load for the cable is not greater than 75 percent of the cable minimum breaking strength.

In some cases it will be necessary to splice one end of the cable on assembly. For this reason, investigate the original installation for pulleys and fair-leads that might restrict the passage of the splice. The procedure for the fabrication of a woven splice is as follows. (Refer to figure 4.12 for the designation of numbers and letters referred to in this sequence of operations.)

(1) Secure the cables around a bushing or thimble, by means of a splicing clamp in a vise, with the free end to the left of the standing wire and away from the operator. If a thimble is used as the end fitting, turn to point outward approximately 45°.

(2) Select the free strand (1) nearest the standing length at the end of the fitting, and free this strand from the rest of the free ends. Next, insert a marlinspike under the first three

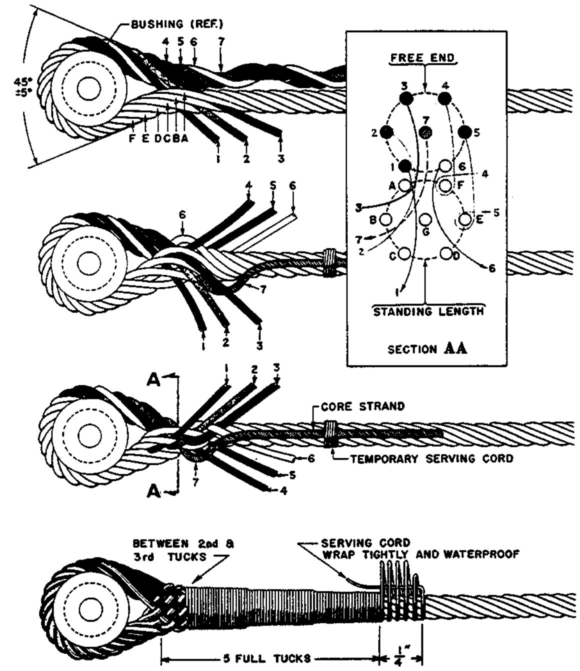


FIGURE 4.12.—Preparation of a woven cable splice.

strands (A, B, and C) of the standing length nearest the separated strand of the free end and separate them momentarily by twisting the marlinspike. Insert the free strand (1) under the three separated strands, through the opening created by the marlinspike. Pull the free end taut by means of pliers.

(3) Unlay a second strand (2), located to the left of the first strand tucked, and insert this second strand under the first two standing strands (A, B). Loosen the third free length (3), located to the left of the first two, and insert it under the first standing strand (A) of the original three (section AA).

(4) Remove the center or core strand (7) from the free end and insert it under the same standing strands (A, B). Temporarily secure the core strand to the body of the standing cable. Loosen the last free strand (6) located just to the right of the first (1) and tuck it under the last two strands (E, F) of the standing cable. Tuck the free strand (5) around standing strand (E). Tuck the free end (4) around the sixth standing strand (F) (see figure 4.12 section AA). Pull all strands snug toward the end fitting with the pliers. This completes the first tuck.

(5) Begin with the first free strand (1) and work in a counterclockwise direction, tucking free strands under every other strand. After the completion of every tuck, pull the strands tight with pliers toward the end fitting. After the completion of the third complete tuck, cut in half the number of wires in each free strand. Make another complete tuck with the wires remaining. At the completion of the fourth tuck, again halve the number of wires in the free strands and make one final tuck with the wires remaining. Cut off all protruding strands and pound the splice with a wooden or rawhide mallet to relieve the strands in the wires.

(6) Serve the splice with waxed linen cord. Start 1/4 inch from the end of the splice and carry the wrapping over the loose end of the cord and along the tapered splice to a point between the second and third tucks. Insert the end of the cord back through the last five wrappings and pull snug. Cut off the end, and if a thimble is used as an end fitting, bend down the points. Apply two coats of waterproofing to the cord, allowing two hours between coats. Carefully inspect the cable strands and splices for local failure. Weakness in a woven splice is made evident by a separation of the strand of serving cord.

b. ***Wrap-Soldered Terminal.*** The wrap-soldered splice terminal shown in figure 4.13 may be utilized on flexible cables less than 3/32 inch in diameter and on nonflexible single strand (19 wire) cable. This type of terminal will develop only 90 percent of the cable strength and should not be used to replace high efficiency terminals, unless it is definitely known that the design load for the cable is not greater than 90 percent of the cable minimum breaking strength. The method of making the wrapped and soldered splice is as follows.

(1) Use serving or wrapping wire made of commercial soft-annealed steel wire or commercial soft iron wire, thoroughly and smoothly tinned or galvanized.

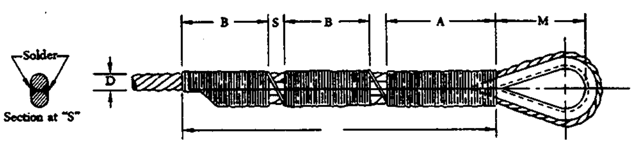
(2) Use half tin and half lead solder conforming to Federal Specification QQ-S-571.

The melting point of this solder varies from 320 to 390° F., and the tensile strength is approximately 5,700 pounds per square inch.

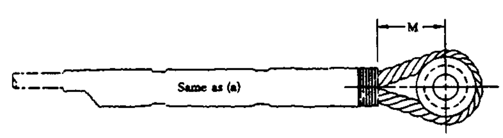
(3) Use solder flux consisting of stearic acid (there should be no mineral acid present) and resin, with a composition of 25 to 50 percent resin. A warming gluepot to keep the flux in fluid state is desirable.

(4) Before the cable is cut, solder the wires to prevent slipping. The preferred process is to tin and solder the cable thoroughly 2 to 3 inches by placing in a solder trough, finishing smooth with a soldering tool. The cable may be cut diagonally to conform to the required taper finish.

(5) After being soldered and cut, the cable is securely bent around the proper size thimble, and clamped so that the cables lie close and flat and the taper end for finish lies on the outside. If it is necessary to trim the taper at this point in the process, it is preferable that it be done by nipping. Grinding is permissible, provided a steel guard at least 3 inches long and 1/32 inch thick is placed between



(a) Soldered & wrapped cable terminal with thimble



(b) Soldered & wrapped cable terminal with bushing

D	L	A	B	M	S	Wrapping wire No. 48-19		Specification No.	
		Plus or minus 1/32"				Dia. inch	Approx. length	Thimble (A)	Bushing (B)
3/32	2-1/4	3/4	5/8	3/4	1/8	.020	37"	AN-100-3	AN-111-3
1/8	2-3/4	1	3/4	3/4	1/8	.025	58"	AN-100-4	AN-111-4
5/32	3-3/8	1-1/8	1	7/8	1/8	.025	82"	AN-100-5	AN-111-5
3/16	3-5/8	1-1/4	1	1-1/8	3/16	.035	109"	AN-100-6	AN-111-6
7/32	4	1-3/8	1-1/8	1-1/4	3/16	.035	--	AN-100-7	AN-111-7
1/4	4-1/2	1-1/2	1-1/4	1-1/2	1/4	.035	159"	AN-100 8	AN-111-8
5/16	5-1/4	1-3/4	1-1/2	1-7/8	1/4	.050	195"	AN-100-10	AN-111-10
3/8	6-1/4	2-1/4	1-3/4	2-1/8	1/4	.050	--	AN-100-12	AN-111-12
7/16	7	2-1/2	2	2-1/2	1/4	.050	--	AN-100-14	------
1/2	8	2-3/4	2-1/4	2-7/8	3/8	.050	--	AN-100 16	------

* FIGURE 4.13.—Preparation of a wrapped soldered terminal. Under Specification No. Bushing (B) column should be used for reference only. Obsolete for procurement. *

the taper end and the main cable during the operation; and that the heat generated from the grinding does not melt the solder and loosen the wires.

(6) Serving may be done by hand or machine, but in either case each serving convolution must touch the adjoining one and be pulled tightly against the cable, with spaces for permitting a free flow of solder and inspection. (See figure 4.13a.)

(7) Prevent drawing of the temper of any cable resulting from excessive temperature or duration of applied heat. Use a soldering flux consisting of stearic acid and resin. The use, as a flux, of sal-ammoniac or any other compound having a corrosive effect is not acceptable.

(8) Soldering is accomplished by immersing the terminal alternately in the flux and in the solder bath, repeating the operation until thorough tinning and filling with solder under the serving wire and thimble is obtained. The temperature of the solder bath and place where terminal is withdrawn should not be above 450° F. A soldering iron may be used in the final operation to give a secure and good-appearing terminal. Assure that the solder completely fills the space under the serving wire and thimble. A slightly hollowed cast-iron block to support the splice during soldering may help in securing the best results. The use of abrasive wheels or files for removing excess solder is not recommended.

(9) As an alternative process for making terminals for nonflexible cable, the oxyacetylene cutting method and the presoldering method (soldering before wrapping) are acceptable, but only under the following conditions:

(a) That the process of cutting securely welds are all wires together;

(b) that the annealing of the cable does not extend more than one cable diameter from the end;

(c) that no filing is done either before or after soldering;

(d) that for protection during the operation of grinding the tapered end of the cable, a steel guard at least three inches in length and 1/32 inch thick should be placed between the taper and the main cable;

(e) that heat from grinding does not draw the temper of the cable.

(10) Do not use wrap-soldered splice terminals ahead of the firewall, or in other fire zones, or in other locations where they might be subjected to high temperature.

198. CABLE SYSTEM INSPECTION. Aircraft cable systems are subject to a variety of environmental conditions and forms of deterioration that ultimately may be easy to recognize as wire/strand breakage or the not-so-readily visible types of wear, corrosion, and/or distortion. The following data will aid in detecting the presence of these conditions:

a. *Cable Damage.* Critical areas for wire breakage are those sections of the cable which pass * through fairleads and around pulleys. To properly inspect each section which passes over a pulley or through a fairlead, remove the cable from the aircraft to the extent necessary to expose that particular section. Examine cables for broken wires by * passing a cloth along the length of the cable. This will clean the cable for a visual inspection, and detect broken wires if the cloth snags on the cable. When snags are found, closely examine the cable to determine the full extent of the damage. The absence of snags is not positive evidence that broken wires do not exist. Figure 4.14 (see (a)) shows a cable with broken wires that were not detected by wiping, but were found during a visual inspection. The damage became readily apparent (figure 4.14b) when the cable was removed and bent using the techniques depicted in figure 4.14c.

NOTE: Tests by various aeronautical agencies have indicated that a few broken wires spread over the length of a cable will not result in a critical loss of strength. Obtain specific information regarding acceptable wire breakage limits from the manufacturer of the aircraft involved.

* Control cables should be removed periodically for a more detailed inspection. Consult the manufacturer's maintenance manual, engineering department, or the FAA for guidance on frequency and procedures. *

(1) External Wear Patterns. Wear will normally extend along the cable equal to the distance the cable moves at that location and may occur on one side of the cable only or on its entire circumference. Replace flexible and nonflexible cables when the individual wires in each strand appear to blend together (outer

*

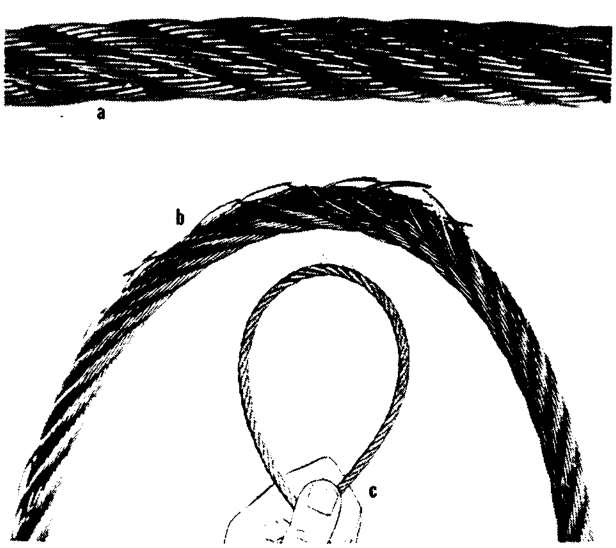


FIGURE 4.14.—Cable inspection technique.

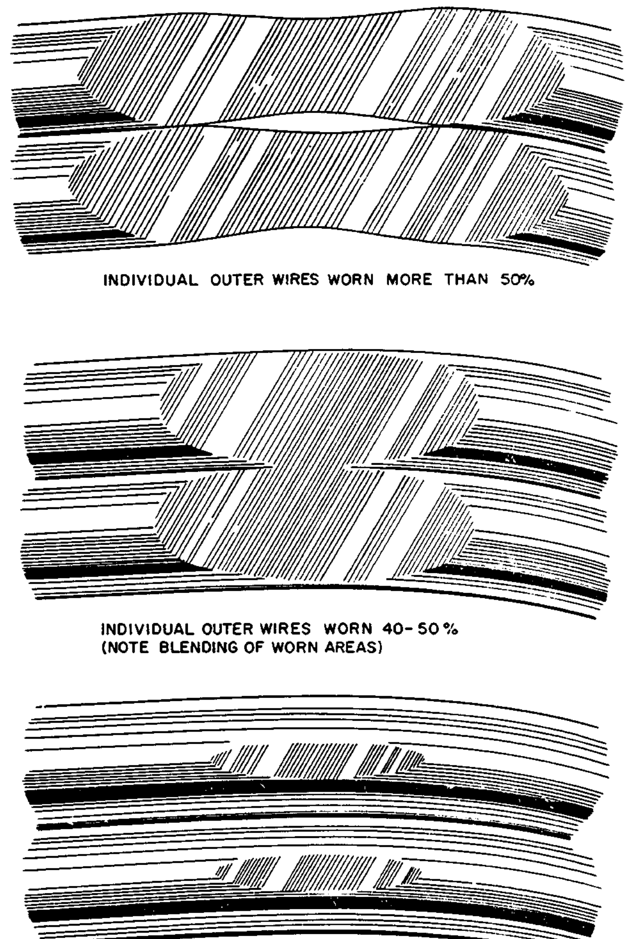


FIGURE 4.15.—Cable wear patterns. *

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FIGURE 4.16.—Worn cable (replacement necessary).

wires worn 40–50 percent) as depicted in figure 4.15. Actual instances of cable wear beyond the recommended replacement point are shown in figures 4.16 and 4.17.

(2) Internal Cable Wear. As wear is taking place on the exterior surface of a cable, the same condition is taking place internally, particularly in the sections of the cable which pass over pulleys and quadrants. This condition (shown in figure 4.18) is not easily detected unless the strands of the cable are separated. Wear of this type is a result of the relative motion between inner wire surfaces. Under certain conditions the rate of this type wear can be greater than that occurring on the surface.

(3) Corrosion. Carefully examine any cable for corrosion that has a broken wire in a section not in contact with wear producing airframe components such as pulleys, fairleads, etc. It may be necessary to remove and bend the cable to properly inspect it for internal strand corrosion as this condition is usually not evident on the outer surface of the cable. Replace cable segments if internal strand rust or corrosion is found.

FIGURE 4.17.—Worn cable (replacement recommended).

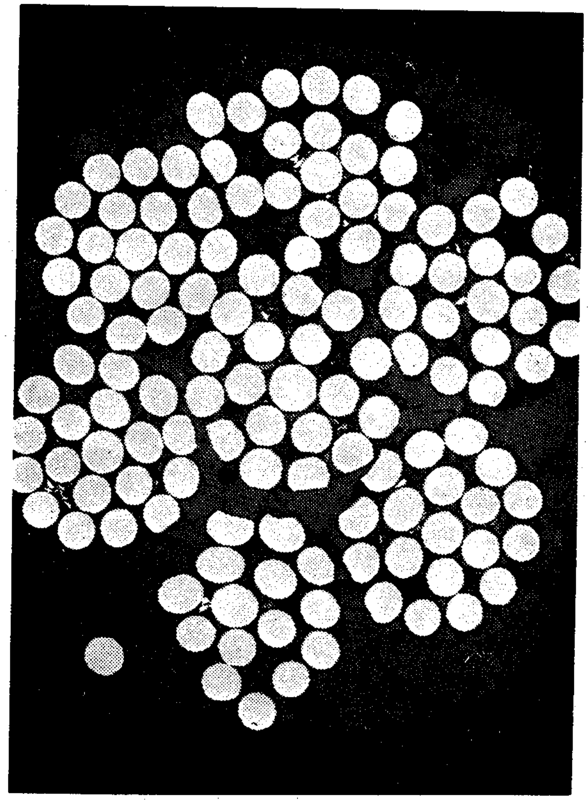

FIGURE 4.18.—Internal cable wear.

Areas especially conducive to cable corrosion are battery compartments, lavatories, wheel wells, etc., where concentrations of corrosive fumes, vapors, and liquids can accumulate.

NOTE: Check all exposed sections of cable for corrosion after a cleaning and/or metal-brightening operation has been accomplished in that area.

An example of cable corrosion, attributable to battery acid, is shown in figure 4.19.

b. *Wire Splices.* Standard manufacturing splices have been mistaken for defects in the cable because individual wire end splices were

Chapter 5. AIRCRAFT HARDWARE

Section 1. IDENTIFICATION AND USE OF AIRCRAFT HARDWARE

227. BOLTS. Most bolts used in aircraft structures are either general purpose Army-Navy (AN) bolts, or National Aircraft Standard (NAS) internal wrenching or close-tolerance bolts. In certain cases, aircraft manufacturers make up special bolts for a particular application and it is necessary to use them or their equivalent in replacement.

a. *Identification.* The AN-type aircraft bolts can be identified by the code markings on the bolt heads. The markings generally denote the bolt manufacturer, the material of which the bolt is made, and whether the bolt is a standard AN-type * or a special purpose bolt. The AN standard steel bolts are marked with either a raised cross or asterisk, corrosion-resistant steel is indicated by a single raised dash, and AN aluminum alloy bolts are marked with two raised dashes. The strength and * dimensional details of AN bolts are specified on the Army/Navy Aeronautical Standard Drawings.

Special purpose bolts include the high-strength type, low-strength type, and close-tolerance type. Such bolts are normally inspected by magnetic, fluorescent, or equivalent inspection methods. Typical markings include "SPEC" (usually highly heat treated), an aircraft manufacturer's part number stamped on the head, or plain heads (low strength). Close-tolerance NAS bolts are marked with either a raised or recessed triangle. The material markings for NAS bolts are the same as for AN bolts, except * that they may be either raised or recessed. Bolts inspected magnetically or by fluorescent means are identified by means of colored lacquer, or a head marking of a distinctive type. Figure 5.1 shows the * typical coding used on aircraft boltheads.

b. *Grip length.* In general, bolt-grip lengths should equal the material thickness. However, bolts of slightly greater grip length may be used provided washers are placed under the nut or the bolt- * head. In the case of plate nuts, if proper bolt-grip length is not available, add shims under the plate. * For proper washers, refer to paragraph 231.

c. *Locking or Safetying of Bolts.* Lock or safety all bolts and/or nuts, except self-locking nuts. Do not reuse cotter pins and safety wire.

d. *Bolt Fit.* Many boltholes, particularly those in primary connecting elements, have close tolerances. Generally, it is permissible to use the first lettered drill size larger than the normal bolt diameter, except where the AN hexagon bolts are used in light-drive fit (reamed) applications and where NAS close-tolerance bolts or AN clevis bolts are used. Boltholes are to be normal to the surface involved to provide full bearing surface for the bolthead and nut, and not be oversized or elongat- * ed. In case of oversized or elongated holes in critical members, consult the manufacturers' structural repair manual, the manufacturers' engineering department, or the Federal Aviation Administration (FAA) before drilling or reaming the hole to take the next larger bolt. Items such as edge distance, * clearance, etc., must be considered.

e. *Torques.* The importance of correct application cannot be overemphasized. Undertorque can result in unnecessary wear of nuts and bolts as well as the parts they are holding together. When insufficient pressures are applied, uneven loads will be transmitted throughout the assembly which may result in excessive wear or premature failure due to fatigue. Overtorque can be equally damaging because of failure of a bolt or nut from overstressing the threaded areas. There are a few simple, but very important, procedures that should be followed to assure that correct torque is applied:

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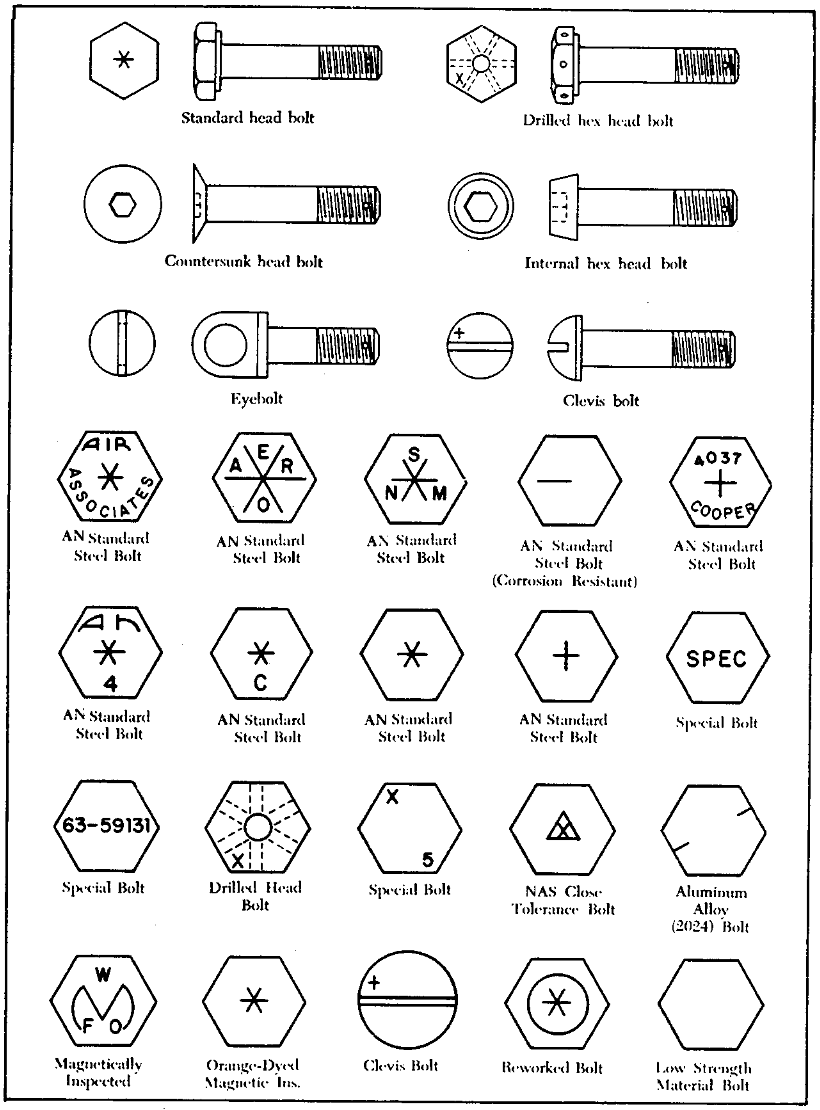

FIGURE 5.1.—Aircraft bolt identification. *

(1) Calibrate the torque wrench periodically to assure accuracy; and re-check frequently.

(2) Be sure that bolt and nut threads are clean and dry (unless otherwise specified by the manufacturer).

(3) Run nut down to near contact with the washer or bearing surface and check "friction drag torque" required to turn the nut.

(4) Add the friction drag torque to the desired torque recommended by the manufacturer, or obtain desired torque as shown in figure 5.2. This is referred to as final torque which should register on the indicator or the setting for a snapover type wrench.

(5) Apply a smooth even pull when applying torque pressure. If chattering or a jerking motion occurs during final torque, back off and re-torque.

(6) When installing a castle nut, start alignment with the cotter pin hole at minimum recommended torque, plus friction drag. If the hole and nut castellation do not align, change washers and try again. Exceeding the maximum recommended torque is not recommended.

b. ***Lock washers (AN-935 and AN-936)*** may be used with machine screws or bolts whenever the self-locking or castellated type of nut is not applicable. They are not to be used as fastenings to primary or secondary structures, or where subject to frequent removal or corrosive conditions.

c. ***Ball-socket and seat-washers (AN-950 and AN-955)*** are used in special applications where the bolt is installed at an angle to the surface, or when perfect alignment with the surface is required at all times. These washers are used together.

d. ***Taper-pin washers (AN-975)*** are used with the threaded taper pin.

e. ***NAS-143 washers*** are used with NAS internal wrenching bolts and internal wrenching nuts. Type "C" is countersunk to seat the bolthead shank radius and a plain-type washer is used under the nut. Both of these washers are heat treated from 125,000 to 145,000 p.s.i.

* 232. TYPES OF RIVETS. (See Figure 5.4.) *

a. ***Standard solid-shank rivets*** and the universal head rivets (AN-470) are used in aircraft construction in both interior and exterior locations.

b. ***Roundhead rivets (AN-430)*** are used in the interior of aircraft except where clearance is required for adjacent members.

c. ***Flathead rivets (AN-442)*** are used in the interior of the aircraft where interference of adjacent members does not permit the use of roundhead rivets.

d. ***Brazierhead rivets (AN-455 and AN-456)*** are used on the exterior surfaces of aircraft where flush riveting is not essential.

e. ***All protruding head rivets*** may be replaced by MS-20470 (supersedes AN-470) rivets. This has been adopted as the standard for protruding head rivets in this country.

f. ***Countersunk head rivets MS-20426*** (supersedes AN-426 100°) are used on the exterior surfaces of aircraft to provide a smooth aerodynamic surface, and in other applications where a smooth finish is desired. The 100° countersunk head has been adopted as the standard in this country.

233. MATERIAL APPLICATIONS.

* **a.** ***2117-T-4 is the most commonly*** used rivet material utilized in aluminum alloy structures. Its * main advantage lies in the fact that it may be used in the condition received without further treatment.

* **b.** ***The 2017-T3, 2017-T31, and 2024-T4 rivets*** are used in aluminum alloy structures where strength higher than that of the 2117-T-4 rivet is needed. See Handbook MIL-HDBK-5 for differences between the two types of 17ST rivets specified here. *

c. ***The 1100 rivets of pure aluminum*** are used for riveting nonstructural parts fabricated from the softer aluminum alloys, such as 1100, 3003, and 5052.

d. ***When riveting magnesium alloy structures,*** 5056 rivets are used exclusively due to their corrosion-resistant qualities in combination with the magnesium alloys.

e. ***Mild steel rivets*** are used primarily in riveting steel parts. Do not use galvanized rivets on steel parts subjected to high heat.

f. ***Corrosion-resistant steel rivets*** are used primarily in riveting corrosion-resistant steel parts such as firewalls, exhaust stack bracket attachments, and similar structures.

g. ***Monel rivets*** are used in special cases for riveting high-nickel steel alloys and nickel alloys. They may be used interchangeably with stainless steel rivets as they are more easily driven. However, it is preferable to use stainless steel rivets in stainless steel parts.

h. ***Copper rivets*** are used for riveting copper alloys, leather, and other nonmetallic materials. This rivet has only limited usage in aircraft.

i. ***Hi-shear rivets*** are sometimes used in connections where the shearing loads are the primary design consideration. Its use is restricted to such connections. It should be noted that hi-shear rivet patterns are not to be used for the installation of control surface hinges and hinge

*

Material	Head Marking	AN Material Code	AN425 78° Counter-Sunk Head	AN426 100° Counter-Sunk Head MS20426*	AN427 100° Counter-Sunk Head MS20427*	AN430 Round Head MS20470*	AN435 Round Head MS20613* MS20615*	AN441 Flat Head	AN442 Flat Head MS20470*	AN455 Brazier Head MS20470*	AN456 Brazier Head MS20470*	AN470 Universal Head MS20470*	Heat Treat Before Using	Shear Strength P.S.I.	Bearing Strength P.S.I.
1100	Plain	A	X	X		X			X	X	X	X	No	10000	25000
2117T	Recessed Dot	AD	X	X		X			X	X	X	X	No	30000	100000
2017T	Raised Dot	D	X	X		X			X	X	X	X	Yes	34000	113000
2017T-HD	Raised Dot	D	X	X		X			X	X	X	X	No	38000	126000
2024T	Raised Double Dash	DD	X	X		X			X	X	X	X	Yes	41000	136000
5056T	Raised Cross	B		X		X			X	X	X	X	No	27000	90000
7075-T73	Three Raised Dashes		X	X		X			X	X	X	X	No		
Carbon Steel	Recessed Triangle				X		X MS20613*	X					No	35000	90000
Corrosion Resistant Steel	Recessed Dash	F			X		X MS20613*						No	65000	90000
Copper	Plain	C			X		X	X					No	23000	
Monel	Plain	M			X			X					No	49000	
Monel Nickel-Copper Alloy	Recessed Double Dots	C					X MS20615*						No	49000	
Brass	Plain						X MS20615*						No		
Titanium	Recessed Large and Small Dot			MS 20426				X					No	95000	

* New specifications are for Design purposes

FIGURE 5.4 Aircraft rivet identification.

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brackets. Do not paint the rivets prior to assembly, even where dissimilar metals are being joined. However, it is advisable to touch up each end of the driven rivet with zinc chromate primer to allow the later application of the general airplane finish.

j. ***Blind rivets*** in the MS-20600 through MS-20603 series rivets and the mechanically-locked stem NAS 1398, 1399, 1738, and 1739 rivets may be substituted for solid rivets in accordance with the blind rivet or aircraft manufacturer's recommendations. They should not be used where the looseness or failure of a few rivets will impair the airworthiness of the aircraft. Design allowables for blind rivets are specified in MIL-HDBK-5, "Metallic Materials and Elements for Flight Vehicle Structures." Specific structural applications are outlined in MS-33522. Nonstructural applications for such blind rivets as MS-20604 and MS-20605 are contained in MS-33557.

* k. ***Identification of solid rivets.*** AN-type aircraft solid rivets can be identified by code markings on the rivet heads. A rivet made of 1100 material is designated as an A rivet, and has no head marking. The 2217-T4 rivets are designated AD rivets, and have a dimple on the head. The 2017-T4 alloy rivets are designated as D rivets and have a raised teat on the head. Two dashes on a rivet head indicate a 2024-T4 alloy designated as DD. A B designation is given to a rivet of 5056-H-12 material and is marked with a raised cross on the rivet head. *

234. FASTENERS (COWL AND FAIRING). A number of patented fasteners are in use on aircraft. A variety of these fasteners are commercially available and the manufacturer's recommendations concerning the proper use of these types of fasteners should always be considered in other than replacement application.

***235. UNCONVENTIONAL ATTACHMENTS.** Do not use unconventional or new attachment devices in the primary structure unless approved by a manufacturer or a FAA representative. *

236.-246. RESERVED.

in any cleaning process to avoid unnecessary breaking of the protective film, particularly at the edges of the aluminum sheet. Chromic acid and other inhibitive treatments tend to restore the oxide film.

d. ***More severe cleaning is necessary*** with intergranular corrosion (attack along grain boundaries). The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of the destruction and to evaluate the remaining structural strength of the component. Inspection with a 5- to 10-power magnifying glass or the use of dye penetrant will assist in determining if all unsound metal and corrosion products have been removed. Grinding to blend or fair out the edges of damaged areas can best be accomplished by using aluminum oxide-impregnated rubber-base wheels. Chemically inhibit the exposed surfaces and restore chemical surface films or paint in the same manner as for other aluminum surfaces.

e. ***Magnesium is the most chemically active*** of the metals used in aircraft construction and is therefore the most difficult to protect. The prompt and complete correction of the coating failure is imperative if serious structural damage is to be avoided. Treat the corroded area with 10 percent chromic acid solution to which has been added approximately 20 drops of battery electrolyte per gallon, in the same manner as for aluminum alloys.

251. CORROSION PROOFING OF LANDPLANES AND SEAPLANES. In the repair or alteration of aircraft, use corrosion proofing materials the same as, or equivalent to, that originally applied unless the repair or alteration would result in increased susceptibility to corrosion, in which case, employ additional corrosion protection measures.

252. CORROSION PROOFING OF LANDPLANES CONVERTED TO SEAPLANES. A special problem is encountered in the conversion of landplanes to seaplanes. In general, landplanes do not receive corrosion proofing to the same extent as do seaplanes manufactured as such. Corrosion-proofing standards for landplanes converted to seaplanes are divided into two classes: (1) Necessary minimum precautions; and (2) Recommended precautions. Regardless of such precautions, it is imperative that the exterior surfaces of seaplanes be washed with clear fresh water immediately following extended water operation, or at least once a day when operated in salty or brackish water. Wash interior surfaces of seaplanes exposed to spray, taking care to prevent damage to electrical circuits or other items subject to injury.

a. ***Necessary Minimum Precautions.*** The following procedures are considered the minimum to safeguard the airworthiness of the converted aircraft and are not in themselves intended to maintain airworthiness for an indefinite period.

(1) Unless already protected, treat exposed fittings or fittings which can be reached through inspection openings with two coats of zinc chromate primer, paralketone, nonwater-soluble heavy grease, or comparable materials. This applies to items such as wing-root fittings, wing-strut fittings, control-surface hinges, horns, mating edges of fittings, and attach bolts, etc.

(2) Coat nonstainless control cables with grease or paralketone or other comparable protective coating, if not replaced with corrosion-resistant cables.

(3) Inspect all accessible sections of aircraft structure. Clean structural parts showing corrosion and refinish if corrosion attack is superficial. If a part is severely corroded, replace with an adequately corrosion-proofed part.

b. ***Recommended Precautions.*** The recommended precautions are those which are suggested as a means of maintaining such aircraft in condition for safe operation over extended periods of time.

(1) Provide additional inspection openings to assist in detecting corrosion. Experience has shown openings to allow inspection of lower and rearward portion of the fuselage to be particularly desirable.

(2) Incorporate additional provisions for free drainage and ventilation of all interiors to prevent collection of moisture (scoop-type drain grommets).

(3) Protect the interior of structural steel tubing. This may be done by air and watertight sealing or by flushing with hot linseed oil and plugging the openings. Inspect tubing for missing sealing screws, presence of entrapped water, local corrosion around sealing screws, welded clusters, and bolted fittings which may be indicative of entrapped moisture.

(4) Slit the fabric of fabric-covered aircraft longitudinally on the bottom of the fuselage and tail structure for access to these sections. Coat the lower structural members with zinc chromate primer (two coats); follow by a coat of dope-proof paint or wrap with cellophane tape and rejoin the fabric. This precaution is advisable within a few months after start of operation as a seaplane.

(5) Spray the interior of metal-covered wings and fuselages with an adherent corrosion inhibitor.

(6) Place bags of potassium or sodium dichromate in the bottom of floats and boat hulls to inhibit corrosion.

(7) Prevent the entry of water by sealing, as completely as possible, all openings in wings, fuselage, control-surface members, openings for control cables, tail-wheel wells, etc.

253. CLEANERS, POLISHES, BRIGHTENERS. It is important that aircraft be kept thoroughly clean of deposits containing contaminating substances such as oil, grease, dirt, and other foreign materials.

a. *Materials.* Avoid damage to aircraft by not using harmful cleaning, polishing, brightening, or paint-removing materials. Use only those compounds which conform to existing government or established industry specifications or products that have been specifically recommended by the aircraft manufacturer as being satisfactory for the intended application. Observe the product manufacturer's recommendations concerning use of his agent.

b. *Chemical cleaners.* Chemical cleaners must be used with great care in cleaning assembled aircraft. The danger of entrapping corrosive materials in fraying surfaces and crevices counteracts any advantages in their speed and effectiveness. Use materials which are relatively neutral and easy to remove.

c. *Removal of Spilled Battery Acid.* In order to neutralize spilled battery acid, use sodium bicarbonate (baking soda), or sodium borate (borax) 20 percent by weight dissolved in water. After neutralization, remove alkali salt completely with large quantities of water to prevent corrosion. An application of acidproof paint to the structure surrounding the battery may be an effective control for this type of corrosion.

254. HANDLING AND CARE OF AIRCRAFT RECOVERED FROM WATER IMMERSION. Aircraft which were recovered from partial or total immersion in water, including flash floods, have been allowed to air dry, in certain instances, with no safety precautions other than a cursory inspection of the aircraft exterior. The lack of an adequate cleanup of water immersed areas may subsequently adversely affect the safety of the aircraft. That is, water immersion increases the probability of corrosive attack, the removal of lubrication, the deterioration of aircraft materials, and/or degradation of electrical and avionic equipment.

Sea water, because of salt content, is more corrosive than surface fresh water. However, fresh water may contain varying amounts of salt and, as drying occurs, the salt concentration is increased and corrosive attack accelerated.

The most important factor following recovery of an aircraft from sea or fresh water immersion is prompt action. Components of the aircraft which have been water immersed, such as the powerplant, accessories, airframe sections, actuating mechanisms, screws, bearings, working surfaces, fuel and oil systems, wiring, radio, and radar should be disassembled, to the extent considered necessary, so that the contaminants can be completely removed.

a. *Initial Fresh Water/Detergent Wash.* As soon as possible after the aircraft is recovered from water immersion, thoroughly wash contaminated internal and external areas of the aircraft using a water/detergent solution as follows:

(1) Mix liquid detergent (MIL-D-16791, Type I) and isopropyl alcohol (TT-I-735) in ratio of 8 parts detergent to 20 parts of alcohol. Add the detergent/alcohol mixture to 72 parts of tap water and mix thoroughly. For use, add one part of the foregoing concentrate to nine parts of tap water (warm water if available) and mix thoroughly.

* **(2)** If the above specified detergent/alcohol materials are not available, use water emulsion cleaning compound (MIL-C-43616). Add one part * compound to nine parts water. If the MIL cleaning compound is not available, use any available mild household detergent solution with fresh tap water.

b. *Safety Precautions.* The following safety precautions should be observed:

(1) Electrically ground the aircraft. Attach the ground lead to the aircraft at a point which is outside the area that could contain explosive vapors.

(2) If the landing gear of land planes is used as a supporting mechanism, install a spreader bar, jury strut, landing gear downlocks or other devices to insure that the gear will not collapse. If the landing gear is not serviceable, insure that the aircraft is solidly supported to prevent hazardous movement.

(3) Disconnect and remove wet- and/or dry-cell batteries and isolate aircraft from all sources of electricity or other spark-producing devices. Spark-producing static electricity is generated at compressed air hose outlets, so this method should not be used for ventilating or purging fuel vapors.

(4) Remove all fuel, oil, and hydraulic fluid.

(5) Flush all fuel and oil cells with clean fresh water.

(6) Deflate tires, especially on magnesium wheels. Depressurize landing gear struts, pneumatic systems, and hydraulic accumulators.

c. *Reciprocating Engines and Propellers.* The propeller should be removed from the engine and the engine from the aircraft. The exterior of the engine and propeller should be washed with steam, or hot or cold fresh water.

The major accessories, engine parts, etc., should be removed and all surfaces flushed with fresh water, preferably hot. If facilities are available, the removed parts, size permitting, should be immersed in hot water or hot oil, 180° F., for a short period of time. Soft water is preferred and should be changed frequently. All parts must be completely dried by air blast or other means. If no heat drying facility is available, wipe the cleaned parts with suitable drying cloths.

The constant speed propeller mechanism should be disassembled, as required, to permit complete decontamination. Clean parts with steam or hot or cold fresh water. Dry the cleaned parts in an oven, but if a heat drying facility is not available, wipe the cleaned parts with suitable drying cloths.

d. *Gas Turbine, Turboprop, and Turboshaft Engines.* The engine exhaust shield, insulation blankets, separate exhaust collectors, compressor housing, pinion cowl and/or upper pinion housing should be removed. The engine accessories, outer housing exhaust shields, and other exposed parts should be steam cleaned. The steam-cleaned parts should be dried in an oven at approximately 200° F., or with hot air from a portable engine heater, or with clean wiping cloths.

Immerse remainder of engine in 10–20 percent water solution of sodium dichromate, or hot, fresh water and apply sufficient agitation to provide complete flushing.

If immersion cannot be accomplished, flood the lower section of the compressor housing and thoroughly flush rotor blades with sodium dichromate solution or warm fresh water. Seal off combustion chamber openings and alternately fill and drain the combustion chamber with fresh air from a portable engine heater or wipe with suitable drying cloths.

e. *Airframe.* The salvageable components of the fuselage, wings, empennage, seaplane and amphibian hulls and floats, and movable surfaces should be processed as follows:

(1) The fabric from fabric-covered surfaces should be removed and replaced.

(2) The aircraft interior and exterior should be cleaned using steam under pressure with steam-cleaning compound. The steam should be directed into all seams and crevices where corrosive water may have penetrated. Avoid steam

* cleaning electrical equipment, such as terminal boards and relays.

(3) Areas that have been steam cleaned should be rinsed immediately with either hot or cold fresh water.

(4) Touch up all scratches and scars on painted surfaces using zinc chromate primer or preservative.

(5) Undrained hollow spaces or fluid entrapment areas should be provided temporary draining facilities by drilling out rivets at lowest point. Install new rivets after drainage.

(6) All leather, fabric upholstery, and insulation should be removed and replaced. Plastic or rubber foam which cannot be cleaned of all corrosive water should be replaced.

(7) All drain plugs or drive screws in tubular structures should be removed and the structure blown out with compressed air. If corrosive water has reached the tubular interiors, carefully flush with hot, fresh water and blow out water with compressed air. Roll the structure as necessary to remove water from pockets. Fill the tubes with hot linseed oil at approximately 180° F. Drain oil and replace drain plugs or drive screws.

(8) Clean sealed wood, metalite, and other nonmetallic areas, excluding acrylic plastics, with warm water. Wood, metalite, and other porous materials exposed to water immersion should be replaced, unless surfaces are adequately sealed to prevent penetration by corrosive water. Virtually all solvents and phenolic type cleaning agents are detrimental to acrylics and will either soften the plastic or cause crazing.

f. *Helicopter Rotor Dynamic Components.*

(1) All evidence of corrosive water should be removed from the exterior of transmissions and gear boxes by flushing with clean hot or cold fresh water.

(2) Where it is possible that corrosive water has reached the interior of the transmission or gear boxes, remove plugs and/or covers and drain completely. Flush interior of part with hot or cold fresh water. Drain residual water, replace plugs and/or covers, and reapply proper lubricant.

g. *Helicopter Blades.* Except for blades with wooden or other nonmetallic constructions, treat helicopter blades the same as propellers for reciprocating engines. Clean nonmetallic blades by hand, using warm water. Dry with wiping cloths or a warm air blast. When cleaning helicopter rotor blades, insure that nonsealed hollow members, such as the spars and blade pockets, are cleaned and dried.

h. *Fuel and Oil Systems.* Contaminated fuel and oil systems should be processed as follows:

(1) Flush oil system, including lines, using water-displacing preservative.

(2) Open fuel systems. Purge cells and fuel lines. Check effectiveness of the purging with combustible gas indicator. Remove bladder and self-sealing type fuel cells and all cavity liners or pads.

(3) Use clean, fresh water to wash fuel cells. After drying, spray interior walls with oil.

(4) Chemically treat bare metal surfaces of cleaned aluminum tanks with 10–20 percent water solution of sodium dichromate.

(5) Flush fuel lines with hot water (150° F. maximum). Dry, using clean, dry, compressed air.

i. *Landing Gear.* Process salvageable components of the landing gear, wheels, and brakes as follows:

(1) Remove tires and wheels.

(2) Steam clean wheels, rinse in fresh water, and dry.

(3) Remove wheel bearings and clean, using dry cleaning solvent.

(4) Immerse bearings in methyl alcohol and dry the cleaned bearings in air blast. Do not permit bearings to rotate during air blast drying. Reapply proper lubricant.

(5) Remove brakes, steam clean, and rinse with fresh water and dry.

j. *Electrical Equipment.*

(1) Wet cell batteries. The risk involved in using wet cell batteries that have been immersed in sea water may outweigh any economic advantage and should be replaced.

(2) Because of possible flight hazards and later defects caused by progressive corrosive attack, all electrical wiring immersed in corrosive water should be replaced. If wiring is * merely splashed or sprayed with corrosive water, flush thoroughly with clean, fresh water and dry * using compressed air. Following compressed air drying, coat with water dispensing preservative (MIL-C-81309, Type II). *

k. *Miscellaneous Equipment.* The following equipment should be thoroughly washed to remove dirt, salt, and other contaminants. Dry with air blast or other means, and, if required, reapply proper lubricant:

(1) Wiring and fuselage hydraulic units.

(2) Electric landing gears.

(3) Actuators.

(4) Cables.

(5) Accumulators.

(6) Hydraulic reservoirs.

(7) Flight control.

(8) Torque tubes and bell cranks.

(9) Heating units, ducts, etc.

255.-264. RESERVED.

Chapter 7. IDENTIFICATION, TESTING, AND INSPECTION OF MATERIALS

Section 1. IDENTIFICATION OF METALS

265. IDENTIFICATION OF STEEL STOCK. The Society of Automotive Engineers (SAE) and the American Iron and Steel Institute (A.I.S.I.) use a numerical index system to identify the composition of various steels. The numbers assigned in the combined listing of standard steels issued by these groups represent the type of steel and make it possible to readily identify the principal elements in the material.

The first digit of the four number designation indicates the type to which the steel belongs. Thus "1" indicates a carbon steel, "2" a nickel steel, "3" a nickel chromium steel, etc. In the case of simple alloy steels, the second digit indicates the approximate percentage of the predominant alloying element. The last two digits usually indicate the mean of the range of carbon content. Thus the symbol "1020" indicates a plain carbon steel lacking a principal alloying element and containing an average of 0.20 percent (0.18 to 0.23) carbon. The symbol "2330" indicates a nickel steel of approximately 3 percent (3.25 to 3.75) nickel and an average of 0.30 percent, (0.28 to 0.33) carbon content. The symbol "4130" indicates a chromium-molybdenum steel of approximately 1 percent (0.80 to 1.10) chromium, 0.20 percent (0.15 to 0.25) molybdenum, and 0.30 percent (0.28 to 0.33) carbon. The basic numbers for the four digit series of the carbon and alloy steels may be found in figure 7.1.

266. INTERCHANGEABILITY OF STEEL TUBING.

a. ***"1025" welded tubing*** as per Specification MIL-T-5066 and "1025" seamless tubing conforming to Specification MIL-T-5066A are interchangeable.

b. ***"4130" welded tubing*** as per Specification MIL-T-6731, and "4130" seamless tubing conforming to Specification MIL-T-6736 are interchangeable.

FIGURE 7.1.—Numerical system for steel identification.

Type of steels	Numerals and digits
Carbon Steels	1xxx
Plain Carbon Steels	10xx
Free Cutting Steels	11xx
Manganese Steels (Manganese 1.60 to 1.90%)	13xx
Nickel Steels	2xxx
3.50% nickel	23xx
5.00% nickel	25xx
Nickel Chromium Steels	3xxx
9.70% nickel, 0.07% chromium	30xx
1.25% nickel, 0.60% chromium	31xx
1.75% nickel, 1.00% chromium	32xx
3.50% nickel, 1.50% chromium	33xx
Corrosion and heat resisting	30xxx
Molybdenum Steels	40xx
Chromium Molybdenum Steels	41xx
Nickel Chromium Molybdenum Steels	43xx
Nickel Molybdenum Steels	
1.75% nickel, 0.25% molybdenum	46xx
* 3.50% nickel, 0.25% molybdenum	48xx *
Chromium Steels	5xxx
Low chormium	51xx
Medium chromium	52xxx
Corrosion and heat resisting	51xxx
Chromium Vanadium Steels	6xxx
1.00% chromium	61xx
National Emergency Steels	8xxx
Silicon Manganese Steels	9xxx
2.00% silicon	92xx

c. ***NE-8630 welded tubing*** conforming to Specification MIL-T-6734, and NE-8630 seamless tubing conforming to Specification MIL-T-6732 are interchangeable.

267. IDENTIFICATION OF ALUMINUM. To provide a visual means for identifying the various grades of aluminum and aluminum alloys, such metals are usually marked with symbols such as Government Specification Number, the temper or condition furnished, or the commercial code marking. Plate and sheet are usually marked with specification numbers or code markings in rows approximately 5 inches apart. Tubes, bars, rods, and extruded shapes are marked with specification numbers or code markings at intervals of 3 to 5 feet along the length of each piece. The commercial code marking consists of a number which identifies the particular composition of the alloy. In addition, letter suffixes designate the following:

Nonheat-treatable Alloys		Heat-treatable Alloys	
Temper designation	Definition	Temper designation	Definition
-O	Annealed recrystallized (wrought products only) applies to softest temper of wrought products.	-O	Annealed recrystallized (wrought products only) applies to softest temper of wrought products.
-H12	Strain-hardened one-quarter-hard temper.	-T2	Annealed (castings only).
-H14	Strain-hardened half-hard temper.	-T3	Solution heat-treated and cold-worked by the flattening or straightening operation.
-H16	Strain-hardened three-quarters-hard temper.	-T36	Solution heat-treated and cold-worked by reduction of 6 percent.
-H18	Strain-hardened full-hard temper.	-T4	Solution heat-treated.
-H22	Strain-hardened and partially annealed to one-quarter-hard temper.	-T42	Solution heat-treated by the user regardless of prior temper (applicable only to 2014 and 2024 alloys).
-H24	Strain-hardened and partially annealed to half-hard temper.	-T5	Artificially aged only (castings only).
-H26	Strain-hardened and partially annealed to three-quarters-hard temper.	-T6	Solution heat-treated and artificially aged.
-H28	Strain-hardened and partially annealed to full-hard temper.	-T62	Solution heat-treated and aged by user regardless of prior temper (applicable only to 2014 and 2024 alloys).
-H32	Strain-hardened and then stabilized. Final temper is one-quarter hard.	-T351, -T451, -T3510, -T3511, -T4510, -T4511.	Solution heat-treated and stress relieved by stretching to produce a permanent set of 1 to 3 percent, depending on the product.
-H34	Strain-hardened and then stabilized. Final temper is one-half hard.	-T651, -T851, -T6510, -T8510, -T6511, -T8511.	Solution heat-treated, stress relieved by stretching to produce a permanent set of 1 to 3 percent, and artificially aged.
-H36	Strain-hardened and then stabilized. Final temper is three-quarters hard.	-T652	Solution heat-treated, compressed to produce a permanent set and then artificially aged.
-H38	Strain-hardened and then stabilized. Final temper is full-hard.	-T81	Solution heat-treated, cold-worked by the flattening or straightening operation, and then artificially aged.
-H112	As fabricated; with specified mechanical property limits.	-T86	Solution heat-treated, cold-worked by reduction of 6 percent, and then artificially aged.
-F	For wrought alloys; as fabricated. No mechanical properties limits. For cast alloys; as cast.	-F	For wrought alloys; as fabricated. No mechanical properties limits. For cast alloys; as cast.

FIGURE 7.2.—Basic temper designations and subdivisions for aluminum alloys.

FIGURE 7.3.—Rockwell C scale steel hardness numbers comparison table—continued.

20	238	226	226	226	**60.5**	97.8	**40.1**	**69.4**	**41.5**	**19.6**	34	110	**20**
(18)	230	219	219	219		96.7					33	106	(18)
(16)	222	212	212	212		95.5					32	102	(16)
(14)	213	203	203	203		93.9					31	98	(14)
(12)	204	194	194	194		92.3					29	94	(12)
(10)	196	187	187	187		90.7					28	90	(10)
(8)	188	179	179	179		89.5					27	87	(8)
(6)	180	171	171	171		87.1					26	84	(6)
(4)	173	165	165	165		85.5					25	80	(4)
(2)	166	158	158	158		83.5					24	77	(2)
(0)	160	152	152	152		81.7					24	75	(0)

[1] The values in this table shown in bold-face type correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E48, table 2.
[2] Values in ( ) are beyond normal range and are given for information only.
[3] It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. Above the level of Rockwell C43, deviation increases with increasing hardness and the table shall not be used above Rc 48 except in the absence of other data specifically approved by the procuring agency.

Section 3. NONDESTRUCTIVE TESTING

295. GENERAL. The field of nondestructive testing (NDT) and inspection is to varied to be covered in detail in this handbook. This section provides a brief description of the various methods that are available for use in aircraft maintenance. The effectiveness of any particular method of NDT inspection depends upon the skill, experience, and training of the persons applying the process. Each process is limited in its usefulness as an inspection tool through its adaptability to the particular component to be inspected. Consult the aircraft or product manufacturer for specific instructions regarding NDT inspection of their product.

296. INSPECTION BY MAGNIFYING GLASS AFTER WELDING. Careful examination of all joints with a medium-power magnifying glass (at-least 10-power), after first removing all scale, is considered an acceptable method of inspection for repaired structures. The practice of filling steel tubular structures with hot linseed or petroleum base oils, under pressure, in order to coat the inside surface and inhibit corrosion, assists in the detection of weld cracks, as the hot oil will seep through cracks invisible to the eye. This practice, though not justifiable in all cases, is suggested where a very large portion of the structure has been rewelded.

* **297. MAGNETIC PARTICLE INSPECTION.** Magnetic particle inspection of Magnaflux can be used only on magnetic material; i.e., iron and steel. Most* stainless or high chromium nickel and manganese alloy steels, being nonmagnetic, cannot be inspected by this method. The method consists essentially of detection of discontinuities (cracks, voids, defects, pits, subsurface holes, etc.) by means of accumulation of magnetic particles on the discontinuities when the part has been magnetized. The magnetic particles are applied either dry as a powder or suspended in light oil. For complete magnetic inspection, both circular and longitudinal, magnetization should be employed.

Caution

Improper operation of Magnaflux equipment because of faulty equipment or by untrained persons, can jeopardize the airworthiness of parts being inspected. Minute electrical arc burns caused during inspection by improper operation of magnaflux equipment, can result in eventual failure of the part.

a. *Circular magnetization* is produced by transmitting an electric current directly through the article being tested, or through a central conductor placed through the part, in which case defects parallel to the flow of current may be detected. As an example, circular magnetization of a round steel bar would be produced by placing the ends of the steel bar between the heads of the magnetic inspection machine and passing a current through the bars. Magnetic particles applied either during or after passage of the current, or after passage of the current in magnetically retentive steels, would disclose discontinuities parallel to the axis of the bar.

b. *Longitudinal magnetization* is induced in a part by placing the part in a strong magnetic field, such as the center of a coil. Thus, longitudinal magnetization of a round steel bar would be produced by placing the ends of the bar between the heads of a magnetic-inspection machine and placing the D.C. solenoid around the bar. After application of the magnetic particles, either during or subsequent to magnetization, discontinuities perpendicular to the axis of the bar would be disclosed.

c. *Red, black, and sometimes gray particles* are used in the wet or dry methods. In the case of wet inspection, a fluorescent magnetic particle may also be used. This process is commercially known as Magnaglo. Articles inspected using the latter medium are illuminated by so-called black light, and the magnetic particles glow by fluorescence causing any defects or indications to be easily visible. The wet inspection procedure provides better control and standardization of the concentration of magnetic particles, easier application to complex shapes, and indications that are easier to interpret. This is due to the difficulty of obtaining efficient distribution of the dry powder during magnetization. The dry procedure is particularly suitable for detecting subsurface defects, such as, when inspecting heavy welds, forgings, castings, etc. The wet continuous process is recommended for most aircraft work.

d. ***The presence of accumulations of magnetic particles*** in magnetic inspection does not necessarily mean that a defect exists. Changes in section of the part, particularly where the change in section is very sharp, and also holes drilled through a part, will frequently cause indications. Surface defects are most easily detected, however, since a crack will cause a sharp line of magnetic particles to appear. Subsurface defects are less easily detected, since only a general collection of magnetic particles will be observed.

e. ***After magnetic inspection*** carefully demagnetize and clean the parts. Examine for possible evidence of electrical arc burns that may have occurred during inspection. All metal particles must be removed and the serviceable parts coated with a suitable preservative.

f. ***Portable type magnetic particle inspection equipment*** such as Sonoflux has been developed for use in the detection of surface or slightly subsurface discontinuities in ferromagnetic aircraft materials and parts. This type equipment usually gives better results when the wet suspension type of indicator, such as that conforming to Specification MIL-I-6868, is used with the powder supplied by the equipment manufacturer. As in other inspection methods, follow the manufacturers' recommendations concerning use of the procedure.

298. X-RAY OR RADIOGRAPHIC INSPECTION. X-ray may be used on either magnetic or nonmagnetic materials for detecting subsurface voids such as open cracks, blowholes, etc. When a photographic film or plate is used to record the X-ray (in a similar manner to exposing a photographic film), the process is known as radiography. When the X-rays are projected through the part onto a fluorescent screen, the process is known as fluoroscopy. The technique used for radiography should be capable of indicating the presence of defects having a dimension parallel to the X-ray beam of 3 percent of the thickness of the part being radiographed for magnesium alloys, and 2 percent for all other metals and alloys. Inspection using a fluoroscopic screen is much less sensitive. Consequently, the radiographic method is usually used for inspection and the fluoroscopic method is used for culling.

a. ***Radiographic inspection*** is extensively used in the aircraft industry for the inspection of all types of castings including sand castings, permanent-mold castings, die castings, etc. X-ray is particularly useful for this application, since it is capable of disclosing defects which exist below the surface, and also since the open types of defects which may occur in castings (shrinks, blowholes, dross inclusions, etc.) are readily disclosed by proper use of X-rays. In the inspection of forged or wrought metals, on the other hand, X-ray inspection is not used so extensively. This is due to the fact that the process of forging or working may cause defects which originally existed in the metal to become tightwalled cracks. Such defects are somewhat difficult to disclose by X-rays. If doubt exists as to the suitability of the X-ray examination, consult a laboratory familiar with the X-ray examination of aircraft parts.

b. ***In radiography,*** values of peak kilovoltage, radiographic density range and penetrometer characteristics are often selected that produce less than optimum radiological data. This selection of high kilovoltage is made in order to reduce the exposure time. The use of too high a kilovoltage reduces the resolvable detail recorded on the radiographic film. As the kilovoltage is increased, X-rays of shorter wave length and greater penetrating power are produced. This presents a sound argument for increased kilovoltages but does not take into account the effects of scatter both within the sample and the radiographic film, which in reality, reduces the resolvability of details recorded on the X-rays.

c. *If for some reason a short exposure time is required,* a faster film is normally used with a higher kilovoltage; however, this has the effect of increasing the granularity and reducing the resolution on the radiographic material.

d. *The use of low voltages* results in improved radiographic signal-to-noise ratio and improved resolution. The recommended kilovoltages are shown in figure 7.5.

FIGURE 7.5—Maximum recommended X-ray kilovolts.

Material	*Atomic No.*	*Max. KV*
Beryllium	4	25
Carbon	6	40
Magnesium	12	50
Alumium	13	75
Titanium	22	120
Steel	22-26	150
Steel	26-28	200
Silver	47	300
Lead	82	1-2 (megavolts)

299. FLUORESCENT PENETRANT. In this method of inspection the article, which may be of metal, plastic material, etc., is first carefully cleaned to permit the fluorescent material to penetrate cracks and defects. It should be noted that cleaning of aluminum may necessitate stripping of any anodizing, since the anodized film, if formed after the defect, could prevent penetration of the fluorescent material and an anodized film tends to hold penetrants which may obscure defect indications. After the article is cleaned, it is either sprayed, painted, or immersed in a bath of fluorescent penetrant. The penetrant is a light oil which has the property of fluorescing or emitting visible light when excited by invisible radiation in the near ultra-violet range (so-called black light). It is important that the penetrant be given sufficient time to penetrate cracks and defects, and for fatigue cracks a minimum of 30 minutes is stipulated by MIL–I–6866. Heat may also be applied to facilitate entry of the penetrant. After the penetrant has had sufficient time to enter any defects, the excess on the surface of the article is washed off by water spray. This washing should be checked by inspection with black light, by which means any penetrant left on the surface may be detected. After washing, a developer is used to bring out the indication. This developer may be in a liquid form or may be a light powder that absorbs the penetrant as it oozes from cracks and defects in the part. The development may also be aided by application of heat to the part. After the indications have been developed, the part is inspected under black light. Any crevices into which the fluorescent material has penetrated will show as luminous areas.

Indications which appear are usually checked by close inspection with a magnifying glass, by etching with a suitable acid or caustic solution, or it may be necessary to cross-section the part, a procedure which, of course, destroys its usefulness. Usually a skilled operator can determine whether an indication actually shows a defect or whether it is a false indication. Also, the internal extent of the defect can sometimes be estimated with fair accuracy. It should be noted that this process of inspection, like all others, has its limitations. If the fluorescent material for any reason is not able to penetrate into a defect, such a defect cannot be detected.

300. DYE PENETRANTS. Several dye penetrant type inspection kits are now available which will reveal the presence of surface cracks or defects and subsurface flaws which extend to the surface of the part being inspected. These penetrant type inspection methods are considered acceptable, provided the part being inspected has been thoroughly cleaned, all areas are readily accessible for viewing, and the manufacturer's recommendations as to method of application are closely followed.

a. *Cleaning.* An inspection is initiated by first cleaning the surface to be inspected of dirt, loose scale, oil, and grease. Precleaning may usually be accomplished by vapor degreasing or with volatile cleaners. Use a volatile cleaner as it will evaporate from the defects before applying the penetrant dye. Sand blasting is not as desirable as a cleaning method, since surface indications may be obscured. It is not necessary to remove anodic films from parts to be inspected, since the dye readily penetrates such films. Special procedures for removing the excess dye should be followed.

b. *Application of Penetrant.* The penetrant is applied by brushing, spraying, or by dipping and allowing to stand for a minimum of 2 minutes. *Dwell time may be extended up to 15 minutes, depending upon the temperature of the part and fineness of the defect or surface condition. Parts being* inspected should be dry and heated to at least 70° F., but not over 130° F. Very small indications require increased penetration periods.

c. *Removal of Dye penetrant.* Surplus penetrant is usually removed by application of a special cleaner or remover, or by washing with plain water and the part allowed to dry. Water rinse may also be used in conjunction with the remover, subject to the manufacturer's recommendations.

d. *Application of developer.* A light and even coat of developer is applied by spraying, brushing, or dipping. When dipping, avoid excess accumulation. Penetrant which has penetrated into cracks or other openings in the surface of the material will be drawn out by the developer resulting in a bright red indication. Some idea of the size of the defect may be obtained after experience by watching the size and rate of growth of the indication.

301. ULTRASONIC FLAW DETECTION. Ultrasonic flaw detection equipment has made it possible to locate defects in all types of materials without damaging the material being inspected. Very small cracks, checks, and voids, too small to be seen by X-ray, are located by means of ultrasonic inspection. An ultrasonic test instrument requires access to only one surface of the material to be inspected, and can be used with either straight line or angle beam testing techniques. The instrument electronically generates ultrasonic vibrations and sends them in a pulsed beam through the part to be tested. Any discontinuity within the part, or the opposite end, will reflect the vibration back to the instrument, which measures the elapsed time between the initial pulse and the return of all reflections and indicates such time lapse on a cathode ray indicator or paper recorder. Ultrasonic inspection requires a skilled operator who is familiar with the equipment being used as well as the inspection method to be used for the many different parts being tested.

302.-312. RESERVED.

Section 4. IDENTIFICATION OF FABRICS AND PLASTICS

313. IDENTIFICATION OF FABRIC. Cotton fabric is often used as covering for wing, fuselage, and control surfaces of aircraft. Acceptable grades of fabric for use on civil aircraft are listed in Chapter 3. In general, the fabric can be readily identified by a continuous marking to show the manufacturer's name or trademark and specification number. This marking may be found stamped along the selvage edge. The specification number for grade "A" fabric is AMS–3806, and for the intermediate grade AMS–3804. The corresponding FAA Technical Standard Order * Numbers for these materials are TSO–C15 and TSO–C14, respectively. Increasing interest in * the use of linen and certain synthetic fabrics in lieu of cotton has been noted. Identity of such materials should always be verified by the user.

314. IDENTIFICATION OF PLASTICS. Plastics cover a broad field of organic synthetic resins and may be divided into two main classifications—thermoplastic and thermosetting plastics.

a. *Thermoplastics*. Thermoplastics may be softened by heat and can be dissolved in various organic solvents. Two kinds of transparent thermoplastic materials are commonly employed in windows, canopies, etc. These materials are known as acrylic plastics and cellulose acetate plastics. These two plastics may be distinguished by the absence of color, the greater transparency, and the greater stiffness of the acrylic as compared to the slight yellow tint, lower transparency, and greater flexibility of cellulose acetate.

b. *Thermosetting Plastics*. Thermosetting plastics do not soften appreciably under heat but may char and blister at temperatures of 204° to 260° C. (400° to 500° F.). Most of the molded products of synthetic resin composition, such as phenolic, urea-formaldehyde, and melamine-formaldehyde resins, belong to the thermosetting group.

315.–320. RESERVED.

U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

Subject: Acceptable Methods, Techniques, and Practices—Aircraft Inspection And Repair

Date: 1988
Initiated by: AVN-113

AC No: 43.13-1A
Change: 3

1. **PURPOSE.** This change transmits new and revised material for Advisory Circular 43.13-1A.

2. **PRINCIPAL CHANGES.** Several charts, figures, grammatical, and editoral errors are corrected. Added information has also been inserted.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
Signature page	1972	Signature page	1988
i	1972	i through xvi	1988
ii through iv-i	1975		
v through xv	1972		
1 through 4	1972	1	1972
		2	1988
		3	1972
		4 through 4-2	1988
25	1972	25	1988
27 through 28	1972	27	1972
		28	1988
73-4	1975	73-4	1975
74	1972	74	1988
81 through 84	1972	81 through 83	1988
		84	1972
87 through 108	1972	87 through 93	1988
		94	1972
		95 through 96	1988
		97	1972
		98	1988
		99	1972
		100 through 101	1988
		102	1972
		103	1988
		104 through 105	1972
		106 through 107-2	1988
		108	1972
115 through 116	1972	115 through 116	1988
121 through 122	1972	121 through 122	1988
127	1972	127	1972
128 through 128-1	1975	128 through 128-1	1988
128-2	1975	128-2	1975

PAGE CONTROL CHART—Continued

Remove Pages	Dated	Insert Pages	Dated
128-3 through 128-4	1975	128-3 through 128-4	1988
129 through 130	1972	129	1988
		130	1972
135 through 139	1972	135	1972
		136	1988
		137	1972
		138 through 139	1988
140	1975	140	1975
143 through 149	1972	143	1972
		144 through 145	1988
		146	1972
		147 through 149-2	1988
150	1975	150	1975
153 through 154	1972	153	1988
		154	1972
159 through 160	1972	159	1988
		160	1972
165 through 166	1975	165 through 165-2	1988
		166	1975
177 through 188	1972	177	1988
		178	1972
		179 through 186	1988
		187	1972
		188 through 188-2	1988
193 through 196	1972	193	1972
		194	1988
		195	1972
		196	1988
199 through 202	1972	199	1972
		200 through 201	1988
		202	1972
205 through 206	1972	205 through 205-2	1988
		206	1972
211 through 212	1972	211	1972
		212	1988
223 through 224	1972	223	1988
		224	1972
233 through 234	1972	233	1972
		234	1988
249 through 250	1972	249	1972
		250 through 250-2	1988
253 through 254	1972	253 through 253-2	1988
		254	1972
267 through 268	1972	267 through 267-2	1988
		268	1972
271 through 272	1972	271 through 272	1988
275 through 276	1972	275 through 275-2	1988
		276	1972
291 through 296	1972	291	1972
		292 through 293	1988
		294 through 295	1972

PAGE CONTROL CHART—Continued

Remove Pages	Dated	Insert Pages	Dated
		296	1988
303 through 304	12/22/76	303	1988
		304	12/22/76
307 through 308	1972	307	1988
		308	1972

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dition, i.e., cleanliness, stretching, fraying, and broken strands. These components must be kept free of petroleum products as they accelerate deterioration of the rubber.

(2) Nose Gear Assembly. Attention should be given to the steering mechanism and should include items such as: torque-links (scissors), torque-tubes, control rods and rod-end bearings, shimmy dampers, cables, and turning stops. In addition, check all nose landing gear components, including mud scrapers and slush deflectors, for damage from natural elements.

(a) Towing of some aircraft with the rudder locks installed may cause damage to the nose steering linkage and rudder control system. Exceeding the steering or towing stops should be followed by a close inspection of the entire nose steering assembly. A broken steering stop will allow turning beyond the design limit, transmitting excessive loads to structures and to the rudder control system. It is recommended that the nose steering arc limits be indicated on the steering collar or fuselage.

(b) Inspect shimmy dampers for leakage around the piston shaft and at fluid line connections, and for abnormal wear or looseness around the pivot points. Also check for proper rigging, "bottoming" of the piston in the cylinder, and the condition of the external stops on the steering collar.

(3) Tailwheels. Disassembly, cleaning, and rerigging of tailwheels are periodically necessary. Inspect for loose or broken bolts, broken springs, lack of lubrication, and general condition. Check steerable tailwheels for proper steering action, steering-horn wear, clearances, and for security and condition of steering springs and cables.

(4) Gear Doors. Inspect gear doors frequently for cracks, deformation, proper rigging, and general condition. Gear door hinges are especially susceptible to progressive cracking, which can ultimately result in complete failure, allowing the door to move and cause possible jamming of the gear. This condition could also result in the loss of the door in flight. In addition, check for proper safetying of the hinge pins and for distorted, sheared, loose, or cracked hinge rivets. Inspect the wheelwells for improper location or routing of components and related tubing or wiring which could interfere with the travel of the gear door actuating mechanisms.

(5) Floats. In order to maintain floats in an airworthy condition, frequent inspections should be made because of the rapidity with which corrosion takes place on aluminum alloy metal parts, particularly when the aircraft is operated in salt water. Examine metal floats and all metal parts on wooden or fiberglas floats for corrosion and take corrective action in accordance with the procedures described in Chapter 6. Repair damage to metal floats in the general manner outlined in Chapter 2 pertaining to aluminum and aluminum alloy structures. In the case of wooden floats, make repairs in accordance with general procedure outlined in Chapter 1. Repair fiberglass floats in accordance with the manufacturer's instructions or other acceptable practices.

(6) Skis and Ski Installation. It is advisable to examine ski installations frequently to keep them maintained in airworthy condition. If shock cord is used to keep the ski runner in proper trim, periodically examine to assure that the cord has enough elasticity to keep the runner in its required attitude and the cord is not becoming loose or badly frayed. Replace old or weak shock cords. When other means of restraint are provided, examine for excessive wear and binding, and replace or repair when such conditions are found. Examine the points of cable attachment, both on the ski and the airplane structure, for bent lugs due to excessive loads having been imposed while taxiing over rugged terrain or by trying to break loose frozen skis. If skis which permit attachment to the wheels and tires are used, maintain proper tire pressure as underinflated tires may push off the wheels if appreciable side loads are developed in landing or taxiing.

(a) Repair of Ski Runners. Fractured wooden ski runners usually require replacement. If a split at the rear end of the runner does not exceed 10 percent of the ski length, it may be repaired by attaching one or more wooden crosspieces across the top of the runner using glue and bolts. Bent or torn metal

runners may be straightened if minor bending has taken place and minor tears may be repaired in accordance with procedures recommended in Chapter 2 relative to repair of metal structures.

(b) Ski Pedestals.

1. Tubular pedestals. Damaged pedestals made of steel tubing may be repaired by using standard tube splices as shown in Chapter 2, figures 2.5 and 2.15.

2. Cast pedestals. Consult a Federal Aviation Administration (FAA) representative on the repair of cast pedestals.

3. Sheet metal pedestals. Repair damaged pedestals made of aluminum alloy sheet in the general manner outlined in Chapter 2.

(7) Wheels. Inspect wheels at periodic intervals for cracks, corrosion, dents, distortion, and faulty bearings in accordance with the manufacturer's service information. In split-type wheels, recondition boltholes which have become elongated due to some play in the through-bolt, by the use of inserts or other suitable means. Pay particular attention to the condition of the through-bolts and nuts. Carefully inspect wheels used with tubeless tires for damage to the wheel flange and for proper sealing of the valve. The sealing ring used between the wheel halves should be free of damage and deformation. In bolting wheel halves together, tighten the nuts to the proper torque value. Periodically accomplish an inspection to assure the nuts are tight and there is no movement between the two halves of the wheel. Maintain grease retaining felts in the wheel assembly in a soft, absorbent condition. If any have become hardened, wash them with a petroleum-base cleaning agent; if this fails to soften them, they should be replaced.

(a) Corrosion of Wheels. Thoroughly clean wheels if corroded and then examine for soundness. Smooth and repaint bare corroded spots with a protective coating such as zinc chromate primer and aluminum lacquer, or some other equally effective coating to prevent further corrosion. Replace wheels having severe corrosion which might affect their strength.

(b) Dented or Distorted Wheels. Replace wheels which wobble excessively due to deformation resulting from a severe side-load impact. In questionable cases, consult the local representative of the FAA concerning the airworthiness of the wheels. Dents of a minor nature do not affect the serviceability of a wheel.

(c) Wheel Bearings. Periodically inspect wheel bearings for condition. Replace damaged or * excessively worn parts. Maintain bearings and races as matched sets. Pack bearings with a high-melting- * point grease prior to their installation. Avoid preloading the wheel bearing when installing on aircraft by tightening the axle nut just enough to prevent wheel drag or sideplay.

(8) Brakes. Maintain the clearance between the moving and stationary parts of a brake in accordance with the manufacturer's instructions. Disassemble and inspect the brake periodically and examine the parts for wear, cracks, warpage, corro- * sion, elongated holes, etc. Discolored brake discs are an indication of overheated brakes and should be replaced. If any of these or other faults are indi- * cated, repair, recondition, or replace the affected parts in accordance with the manufacturer's recommendations. Surface cracks on the friction surfaces of the brake drums occur frequently due to high surface temperatures. These surface cracks may be disregarded as seriously affecting the airworthiness until they become cracks of approximately 1 inch in length.

(a) Hydraulic Brakes. For proper maintenance, periodically inspect the entire hydraulic system from the reservoir to the brakes. Maintain the fluid at the recommended level with proper brake fluid. When air is present in the brake system, bleed in accordance with the manufacturer's instructions. Replace flexible hydraulic hose which has deteriorated due to long periods of service and replace hydraulic piston seals when there is evidence of leakage. Service antiskid units according to the manufacturer's instructions.

* "327(8)(b). [Deleted] — Change 3" *

(9) Micro-Switches. Inspect micro-switches for security of attachment, cleanliness, general condition, and proper operation. Check associated wiring for chafing, proper routing, and to determine that protective covers are installed on wiring terminals, if required. Check the condition of the rubber dust boots which protect the micro-switch plungers from dirt and corrosion.

328. CLEANING AND LUBRICATING. It is recommended that only easily removable neutral solutions be used when cleaning landing gear components. Any advantage, such as speed or effectiveness, gained by using cleaners containing corrosive materials, can be quickly counteracted if these materials become trapped in close-fitting surfaces and crevices. Wear points, such as landing gear up-and-down latches, jack-screws, door hinges, pulleys, cables, bell-cranks, and all pressure-type grease fittings should be relubricated after every cleaning operation. To obtain proper lubrication of the main support bushings, it may be necessary to jack the aircraft.

NOTE: Anytime the aircraft is on jacks, check the landing gear main support bushings for wear. Consult the aircraft manufacturer's overhaul manual for specific wear tolerances.

During winter operation, excess grease may congeal and cause increased loads on gear retraction system electric motors and hydraulic pumps. This condition can lead to component malfunctions; therefore, it is recommended that cleanliness be stressed during and after lubrication.

329. EMERGENCY SYSTEMS. Exercise emergency landing gear systems periodically to insure proper operation and to prevent inactivity, dirt, and corrosion from rendering the system inoperative when needed. Most emergency systems employ either mechanical, pressure-bottle, or free-fall extension capabilities. Check for proper safetying of triggering mechanisms, and for the presence of required placards and necessary accessories such as cranks, levers, handles, etc.

330. SPECIAL INSPECTIONS. Any time an aircraft has experienced a hard or overweight landing, it is recommended that a special structural inspection, which includes the landing gear, be performed. Typical areas which required special attention are landing gear support trusses for cracked welds, sheared bolts and rivets, and buckled structures; wheels and tires for cracks and cuts; and upper and lower wing surfaces for wrinkles, deformation, and loose or sheared rivets. If any damage is found, a detailed inspection is recommended.

331. RETRACTION TESTS. Periodically, perform a complete operational check of the landing gear retraction system. Inspect the normal extension and retraction system, the emergency extension system, and the indicating and emergency warning system. Determine that the actuating cylinders, linkage, slide tubes, sprockets, chain or drive gears, gear doors, and the up-and-down locks are in good condition and properly adjusted and lubricated. In addition, an electrical continuity check of micro-switches and associated wiring is recommended. Only qualified personnel should attempt adjustments to the gear position and warning system micro-switches, and then only by closely following the manufacturer's recommendations.

332. TIRES. It is essential that tires be inspected frequently for cuts, worn spots, bulges on the sidewalls, foreign bodies in the treads, and tread condi-
* tion. Defective or worn tires may be repaired or retreaded in accordance with the following paragraphs. The term, "retread," for the purpose of this *
advisory circular, refers to the several means of restoring a used tire, whether by applying a new tread alone or tread and sidewall material in varying amounts. It refers as well to the process of extending new sidewall material to cover the bead area of the tire. Repairs are included in the retreading of tires. Aircraft tires are identified by type and rating (figure 8.6).

Type	MFG under FAR 37.167 (TSO C62)	Design and rating
I	No	Smooth contour.[1]
II	No	High pressure.[1]
III	Yes	Low pressure.[2]
IV	No	Extra low pressure.[1]
V	No	N/A.
VI	No	Low profile.[1]
VII	Yes	Extra high pressure "low speed".[2]
VII	Yes	Extra high pressure "high speed." [3]
VIII	Yes	Extra high pressure—Low profile "low speed." [2]
VIII	Yes	Extra high pressure—low profile "high speed." [3]

[1] Inactive for new design.
[2] Low speed for ground speeds below 160 m.p.h.
[3] High speed for ground speeds above 160 m.p.h.

FIGURE 8.6.—Aircraft tire types and ratings.

Tires rated for groundspeeds in excess of 160 m.p.h. have the type and rating embossed on the sidewall.

a. *Repair and Retreading of Low-Speed Tires.* The following procedures are applicable to other than Type VII and Type VIII high-speed aircraft tires.

(1) Tires having injuries of the following types may be repaired:

(a) ***Bead injuries*** where only the chafe resistant material is damaged or loose, or where minor injuries do not penetrate into more than 25 percent of the tire plies, up to a maximum of three damaged plies.

(b) ***Injuries in tread or sidewalls*** may be repaired by the spot repair method. This includes cuts in the tread area that are smaller than 1/2 inch in length and do not penetrate more than the following number of plies into the cord body.

Ply rating:	*Maximum cut depth*
Less than 8	None.
8 through 16	2 plies.
More than 16	4 plies.

(2) Nonrepairable Tires. If any of the following conditions exist, repair of the tire is not recommended:

(a) Evidence of flex breaks.

(b) Bead injuries that exceed the limits outlined in paragraph (1) (a) or affect the seal of the bead on tubeless-type tires.

(c) Evidence of separation between plies or around bead wire.

(d) Injuries requiring reinforcement. This includes injuries larger than those outlined under paragraph (1) (b) and all injuries requiring sectional repair.

(e) Kinked or broken beads.

(f) Weathering or radial cracks extending into the cord body.

(g) Evidence of blisters or heat damage.

(h) Cracked, deteriorated, or damaged inner liners of tubeless tires.

(3) Spot Repairs. Use repair methods conforming to the best aviation industry practices. Skive injuries require spot repairs at an approximate 45° angle to remove damaged rubber and cords.

Buff away exposed cord (refer to paragraph (1) (b) for cord damage limits) leaving only the ends at the skive line and the rubber between the cord plies exposed. Clean the area thoroughly before applying the vulcanizing cement. As soon as the cement is completely dry, cover the skived area of the carcass with repair cushion gum. Fill the cavity in the carcass with repair cushion gum and roll to remove air. The tread cavity can then be filled with tread repair gum well-rolled, to provide a solid repair.

(4) Bead or Chafe Repairs. Use repair methods conforming to the best aviation industry practices. Trim the frayed fabric ends. Turn back the loose area, buff and clean the surface, and immediately cement. Secure the fabric back in position. Vulcanize repairs larger than 2 inches.

(5) Retreadable Tires. Tires which are sound or which can be repaired as listed above may be retreaded as set forth in Specification MIL-R-7726.

(6) Marking of Retreaded Tires. Permanently mark each retreaded tire. Whenever it is necessary to replace the area containing the original marking, such markings must be replaced. In addition, each retreaded tire will:

(a) Display the letter "R" followed by a number "1", "2", etc., to signify the sequential number of retreads applied thereon.

(*b*) Display the speed category increase if the tire is qualified for the increased speed in accordance with the requirements specified in Federal Aviation Regulations (FAR) 37.167 (Technical Standard Order TSO-C62).

(*c*) Display the month and year of retread application.

(*d*) Display the name of the person retreading the tire.

(7) Balance. Each repaired or retreaded tire should not exceed the static unbalance limits as set forth in TSO-C62.

(8) Tire Installation. Install the tire on the wheel in such a manner that the tire-bead chafing area will not be torn or the tube pinched during the mounting process. When mounting tubeless tires, use procedures that assure a positive seal between the tire-bead and the wheel-rim area.

(9) Clearance. For retractable landing gears, maintain sufficient clearance between the tire and the surrounding structure during the retraction process. Carefully check clearances following installation of wheel assemblies equipped with retreaded tires because of the growth factor which may have increased the tire diameter and cross section.

b. *Retreading Types VII and VIII High-Speed Tires.* The following paragraphs describe ways of substantiating the acceptability of methods, techniques, and practices to be used in retreading of high-speed tires. Other methods may be used.

(1) Number of Retreads. The wide variation in tire operating environments which may affect total carcass life and serviceability makes it inadvisable to prescribe arbitrarily the maximum number of times a high-speed tire should be retreaded. This * aspect is controlled by thorough inspection of the carcass, applying such methods as air needle injection or nondestructive testing. *

(2) Condition of Tire to be Retreaded. Retread only those tire carcasses found serviceable by thorough inspection. During inspection, use equipment, techniques, and procedures which are recommended by the tire manufacturer or that are equivalent to those in general use by FAA certificated repair agencies rated for retreading of high-speed aircraft tires. Determine the acceptability of damaged tires for retreading in accordance with established industry practices.

(3) Retreading Criteria.

(*a*) Processes, Methods, Techniques, Practices, and Equipment. The suitability of specific retread manufacturer's injury limitations, retreading processes, and equipment used is determined either by satisfactory service experience or substantiating tests.

(*b*) Materials. The acceptability of materials used in a retreading process may be determined by following the tire manufacturer's recommendations, or the materials may be substantiated by analysis and tests, such as dynamometer testing, or through satisfactory service experience.

(*c*) Unbalance. The moment of static unbalance in ounce-inches shall be no greater than the following moment values:

1. Tire diameters up to and including 28 inches: Moment $= .01D^2 + .38D$.

2. Tire diameters greater than 28 inches: Moment $= .034D^2 - .304D$.

D = Tire diameter (actual).

(*d*) Balance Marker. To indicate the lightweight point of the tire, remove old balance marker, and durably affix a new relocated balance marker, consisting of a single red dot of appropriate size to the sidewall of the tire immediately above the bead.

(*e*) Burst Pressure. Retreaded tires shall be capable of withstanding without failure, a burst pressure of at least 3 times the rated inflation pressure.

(*f*) Temperature. The airworthiness of retreaded tires shall not be adversely affected as a result of their being subjected to extreme ambient temperatures expected to be encountered during normal airplane operation.

(*g*) Tread Design. Substantiate decreases or increases in the number of tread ribs, grooves and changes in skid depth by dynamometer tests that are applicable to the tire groundspeed range.

(*h*) Underskid Thickness. The thickness of the rubber between the carcass and the bottom of the tread pattern (underskid) is not normally less than 30 percent of the mold skid depth. Requalify by dynamometer test, tire underskid/tread thickness which is greater than that previously qualified.

* (*i*) Venting. Substantiate changes in venting pattern by dynamometer test. Existing vent holes should be rebored if they do not vent during air needle test or if covered during the retreading process.

(*j*) Tire Weight. Tire weight will not be greater than 105 percent of the manufactured new tire weight or exceed the applicable aircraft type certificate limitations, whichever is more restrictive.

(*k*) Liner Leak/Separation Check. Tires will be checked for liner leaks, separations, and proper venting. This check is to be performed before and after the tire has been retreaded for those tires on which a liner repair has been made. Balance pads must be removed prior to the initial liner leak check.

(*l*) Cross Treading. Every effort should be made by the owner/operator to assure that no tire will be retreaded by other than the retreader of the original worn casing. Differences in materials, techniques, and procedures could cause noncompatability of the retread to the casing which may result in tire failure. *

(4) Marking and Identification. Do not obliterate the original manufacturer's marking and identifying data, unless it is necessary for proper retreading or repair. Permanently emboss the tire sidewall with retread information. If necessary, replace original identifying markings and include the following retread identification:

(*a*) Name of identifying letters of the retreading company.

(*b*) The letter "R" followed by a numeral "1", "2", etc., to signify first, second, etc., time the tire has been retreaded.

(*c*) Plant location of the retread manufacturer.

(*d*) Month and year of retread in numerical figures.

(*e*) If the dynamometer retread qualification speed is less than the previous (original) tire qualification speed, remove the previous speed marking and indicate the new (lower) rated speed. Identify tires that have been retreaded for use only on aircraft of a specific make/model and type design.

(5) Quality Control. The retreader's quality control system will be expected to maintain a satisfactory level of workmanship throughout the retreaded process including assurance that each retreaded tire is vented to prevent tread breakdown or separation.

(6) Records of Work Performed. Include at least the following information in the retreader's work record for each tire processed:

(*a*) Tire size.

(*b*) Ply rating.

(*c*) Speed rating.

(*d*) Serial number.

(*e*) Retread number.

(*f*) Type of tread applied.

(*g*) Month and year applied.

(7) Dynamometer tests. An acceptable means of determining that the methods, techniques, and practices utilized in the retread process will produce a tire that meets the requirements of FAR 43.13 is by subjecting a representative tire to the following dynamometer tests:

(*a*) General. Load-speed-time data compiled by the aircraft manufacturer is the basis for establishing representative dynamometer tests. To determine tire performance, simulate the most critical combination of takeoff weight, speed, and airplane center-of-gravity position. Also, consider increased speeds resulting from elevated airport operations and high ambient temperatures.

(*b*) Selection of Tires for Qualification Testing. Retread only tires that are worn at least 80 percent from actual aircraft usage or which have undergone simulated equivalent operation during dynamometer testing. The sample retreaded tire must be properly identified and bear the qualifying retreaders markings.

(*c*) Test Inflation Pressure. Inflate the sample tire to the pressure necessary to obtain the

* same deflection on the flywheel (under the rated static load) as the flat-plate deflection the tire would have at its rated static load and inflation.

(d) Test Speeds. The applicable dynamometer test speeds corresponding to the maximum operational groundspeeds (see page 149): *

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*

Maximum operational ground speed of aircraft (m.p.h.)		Dynamometer test speed (m.p.h.)
Over	*Not over*	
160	180	180
180	200	200
200	225	225
225	250	250

(e) Test Landing Interval. Schedule minimum time between landings to assure carcass peak temperatures of not less than 160° F. or contained air peak temperatures of not less than 140° F. for each run. Measure the carcass temperatures within 1 inch of the rim flange and also in the shoulder or crown area. Record any unavoidable deviations in the substantiating test data.

(8) Dynamometer Test Procedures. The high-speed retreaded tire shall withstand 100 dynamometer landings and at least 3 taxi-test cycles. The dynamometer landings will consist of 50 Test A, load-speed-time cycles, and 50 Test B, energy cycles.

(a) Test A, Load-speed-time.

1. Speed cycle. Land the tire against a dynamometer flywheel rotating at a peripheral speed of S_1 m.p.h. Immediately thereafter, decrease the flywheel speed at an average deceleration rate of D ft./sec./sec. until a value of S_2 is attained. No specific rate of deceleration is required after the flywheel's peripheral speed reaches a value of S_2. Decrease the speed of the flywheel in the above manner until a roll distance of RD feet has been covered, at which time the tire is unlanded.

2. Load cycle. After landing, increase the load from zero to L_1 pounds within T_1 seconds. Linearly increase the load with time to a value of L_2 pounds within T_2 seconds after landing, or at the moment of unlanding, whichever occurs first. If it is necessary to continue the roll after T_2 seconds to complete the required roll distance (RD), maintain the load at L_2 pounds.

3. Symbol definitions. Determine the numerical values, which are used for the following symbols, from the applicable airplane load-speed-time data:

S_1 = Initial dynamometer test speed.

S_2 = Speed at which the average deceleration between S_1 and S_2 does not exceed the specified value.

D = Constant rate of deceleration between S_1 and S_2 speeds.

RD = Roll distance in feet.

L_2 = Maximum rated static load of the tire.

T_1 = Time for applying L_1 load. A T_1 tolerance of ± 1 second is acceptable.

$$T_2 = \frac{S_1 - \sqrt{S_1^2 - 2D\,(RD)}}{D}$$

T_2 is the elapsed time for applying the L_2 load. A T_2 tolerance of +10 percent is acceptable. When T_2 is calculated by the aforementioned formulas, S_2 may be ignored and D is assumed constant throughout roll distance (RD).

4. Test load adjustment. If the test load curve results in loads at a given speed being less than those dictated by the applicable aircraft data, eliminate the condition by making adjustments in T_2, L_1, and/or T_1.

(b) Test B, Energy.

1. Kinetic energy. Calculate and adjust the kinetic energy of the flywheel for the rated maximum static load of the tire. In the event that the correct number of flywheel plates cannot be used to obtain the calculated kinetic energy value or proper flywheel width, select a greater number of plates and adjust the dynamometer speed to achieve the required kinetic energy.

2. Kinetic energy computation. Computer kinetic energy as follows:

$KE = CWV^2$

Where

KE = Kinetic energy, ft.-lb.
C = 0.011
W = tire load, pounds
V = 120 m.p.h.

3. Speed cycle. Land the test tire at 90 m.p.h. and unland at 0 m.p.h. Decrease the landing speed as necessary to assure that 56 percent of the calculated kinetic energy is absorbed by the tire.

4. Load cycle. Upon landing, and during the entire roll test, force the tire against the flywheel at its rated static load. *

* **(c)** Taxi Test.

1. Test parameters. Conduct a minimum of three dynamometer taxi tests under the following conditions:

Speed = 35 m.p.h.
Tire Load = Maximum static rating.
Roll Distance = 35,000 feet.

2. Tire temperature. Heat the test tire to a temperature of not less than 120° F. at the start of each of the three taxi test cycles. Rolling the tire on the dynamometer is acceptable in obtaining this minimum tire temperature. Make no adjustments in the tire inflation pressure to compensate for increases due to temperature rise.

(9) Alternate Dynamometer Tests.

(a) Variable Loading. An alternate dynamometer test which more realistically simulates actual airplane performance on the runway may be used in lieu of the deceleration load-speed-time schedule. An acceleration load- *

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actual airplane performance on the runway may be used in lieu of the deceleration load-speed-time schedule. An acceleration load-speed-time schedule, wherein the dynamometer flywheel is accelerated to the applicable conditions, is acceptable.

(b) Alternate Procedure for Reinforced-tread Tires. Qualification of a high-speed tire with a given ply rating and reinforced tread will automatically qualify a lesser ply rating reinforced tread tire of the same size and skid depth, provided:

1. The test conditions S_1, RD, S_2, T_1, and T_2 are no less severe than those which are applicable to the lesser ply rating tire.

2. The ratio of the test loads, L_1 to L_2 is not less than that applicable to the lesser ply rating tire. Make any necessary adjustment in this ratio by increasing L_1.

(10) Optional Dynamometer Equipment. Dynamic tests may be conducted on any dynamometer test equipment which will provide the load, speed, time, and roll distance parameters of the tire.

c. Tubes. Punctured tubes may be repaired by the use of cemented or vulcanized patches.

(1) The procedure for making such repairs is substantially identical to that used in connection with repair of automobile tires:

(a) Keep the size of the patch to a minimum and avoid use of an excessive number of patches, particularly in one area, as the weight of the material may contribute to excessive wheel vibration due to the tube being out-of-balance.

(b) The use of vulcanized patches is recommended because they are considered more reliable.

(c) Reinstalled tires should be inflated, deflated, and again inflated to insure that the inner-tube is not pinched. A pinched tube will chafe against the walls of the carcass and a thin spot will result in the rubber. In time, the tube wall will leak at this point. The pinching generally is due to the sticking of the tube to the carcass wall during the first inflation and the failure of the carcass to properly seat against the flange.

(d) The tube is then confined to a smaller space and wrinkling (pinching) of the tube results. Complete deflation followed by inflation allows the tube to properly accommodate itself to the carcass which should now seat itself tightly against the flanges.

* **333. TIRE SLIPPAGE.** To reduce the possibility of tire and tube failure due to slippage, and to provide a means of detecting tire slippage, tires should be marked and indexed with the wheel rim. Marking should be accomplished by painting a mark 1 inch in width and 2 inches in length across the tire sidewall and wheel rim. The paint used should be of a permanent type and contrasting color, such as white, red, or orange. Preflight inspection should include a check of slippage marks for alignment. If the slippage mark is not in alignment, the aircraft should not be operated until a detailed inspection is made, the reason determined, and if necessary the condition corrected.

334. TIRE MAINTENANCE. A program of tire maintenance can minimize tire failures and increase tire service life. Overinflation wears the center of the tread excessively, and reduces a tire's resistance to bruising, strains the tires beads, reduces traction and skid resistance. Underinflation increases deflection and may cause breakdown of the tire sidewalls. The manufacturer's recommendations should be followed to obtain maximum tire service life.

345.–349. RESERVED. *

Section 3. MISCELLANEOUS EQUIPMENT

360. PARACHUTES. With reasonable care, parachutes normally last at least 5 years. They should not be carelessly tossed about, left in airplanes so that they may become wet, or left in open places where they may be tampered with. They should not be placed where they may fall on oily floors or be subject to acid fumes from adjacent battery chargers. When repacking is scheduled, a careful inspection of the parachute should be made by a qualified parachute technician (rigger). If repairs or replacements of parts are necessary to maintain the airworthiness of the parachute assembly, such work must be done by the original parachute manufacturer or by a qualified parachute rigger, certificated in accordance with FAR Part 65, or by an appropriately rated parachute loft certificated in accordance with FAR Part 149.

* **361. SAFETY BELTS.** The FARs require that when safety belts are to be replaced in aircraft manufactured after July 1, 1951, such belts must conform to standards established by the FAA.* These standards are contained in Technical Standard Order TSO-C22. Safety belts eligible for installation in aircraft may be identified by the marking TSO-C22 on the belt or by a military designation number since military belts comply with the * strength requirements of the TSO. Each safety belt must be equipped with an approved metal to metal latching device. Airworthy type-certificated safety * belts currently in aircraft may be removed for cleaning and reinstalled. However, when a type-certificated safety belt is found unairworthy, replacement it with a TSO-C22 or a new belt is preferred.

* **a.** ***The webbing of safety belts,*** even when mildew-proofed, is subject to deterioration due to constant use, cleaning, and the effects of aging. Fraying of belts is an indication of wear, and such belt are likely to be unairworthy because they can no longer hold the minimum required tensile load. * Difference of opinion as to the airworthiness of a belt can be settled by testing a questionable belt to demonstrate that it will support the required load. Airworthy one-person type-certificated belts should be able to withstand a tensile load of 525 pounds, and TSO belts withstand the rated tensile load indicated on the belt label. Most one-person TSO belts are rated for 1,500 pounds. For two-person belts, double the loads. Since type-certificated belts will not afford the crash protection provided by a TSO or military belt, such type-certificated belts are not to be repaired nor should their buckles or end fittings be reused on safety belts. If replacement of webbing or hardware of TSO or military belt is attempted, use parts of identical design and material. Make the stitch pattern identical to the original and the number of stitches per inch equal to the number used in the original belt. There is no objection to having a greater total length of stitching, provided one line of stitches is not placed over another line. Space lines of stitching at least 3/16-inch apart. Keep a record, preferably in the logbook, stating the extent to which the belt was repaired and the date. Retain the original identification marking on the belt, conforming either to that required by TSO-C22 to a deviation from this marking, or to the military designation. Operators of a fleet of airplanes should follow the above suggestions, but keeping a record of renovations in a logbook is impractical, since the belts are never associated with any one particular aircraft for any length of time. Therefore, in addition to retaining the original identification label and attaching it to the renovated belt, use some additional simple marking to indicate

that the belt has been renovated and show the date of renovation. The use of letter "R" followed by the date would be acceptable. This marking could be in the form of an indelible ink stamping or cloth label stitched to the webbing.

362. FLARES. Parachute flares are made of materials which are subject to decomposition upon aging. Humidity affects the small igniting charge and also the materials of the candle (illuminant). Hence, the percentage of misfires in old flares is likely to be quite high. To assure unfailing performance of flares, periodically inspect the flare installation. Inspect the entire system, starting at the release mechanism in the cockpit and ending at the flare. Only a qualified person should attempt such inspection, since inadvertent discharge of such pyrotechnics may cause serious damage. Past experience has indicated that it is advisable to return all electrically or pistol-operated flares to the manufacturer for reconditioning within a maximum period of 3 years, and that for mechanically operated flares, a maximum period of 4 years is recommended.

363. OXYGEN SYSTEMS.

a. *General.* The following instructions are to serve as a guide for the inspection and maintenance of aircraft oxygen systems. The information is applicable to both portable and permanently installed equipment.

(1) Aircraft Gaseous Oxygen Systems. The oxygen in gaseous systems is supplied from one or more high- or low-pressure oxygen cylinders. Since the oxygen is compressed within the cylinder, the amount of pressure indicated on the system gauge bears a direct relationship to the amount of oxygen contained in the cylinder. The pressure-indicating line connection is normally located between the cylinder and a pressure-reducing valve.

NOTE: Some of the gaseous oxygen systems do not use pressure-reducing valves. The high pressure is reduced to a useable pressure by a regulator. This regulator is located between the high- and low-pressure system.

(2) Aircraft Liquid Oxygen Systems. Thus far it has not been a practice to use liquid oxygen in civil aircraft due to its complexity. This however, may change at any time as technological advances are made.

(3) Portable Oxygen Systems. The three basic types of portable oxygen systems are: demand, pressure demand, and continuous flow. The component parts of these systems are identical to those of a permanent installation with the exception that some parts are miniaturized as necessary. This is done in order that they may be contained in a case or strapped around a person's shoulder. It is for this portability reason that it is essential special attention be given to assuring that any storage or security provision for portable oxygen equipment in the aircraft is adequate, in good condition, and accessible to the user.

NOTE: Check portable equipment including its security provisions frequently, as it is more susceptible to personnel abuse than a permanently installed system.

b. *Inspection.* Hands, clothing, and tools must be free of oil, grease, and dirt when working with oxygen equipment. Traces of these organic materials near compressed oxygen may result in spontaneous combustion, explosions, and/or fire.

(1) Oxygen Tanks and Cylinders. Inspect the entire exterior surface of the cylinder for indication of abuse, dents, bulges, and strap chafing.

(a) Examine the neck of cylinder for cracks, distortion, or damaged threads.

(b) Check the cylinder to determine if the markings are legible.

(c) Check date of last hydrostatic test. If the periodic retest date is past, do not return the cylinder to service until the test has been accomplished.

NOTE: This test period is established by the Department of Transportation in the Code of Federal Regulations, Title 49, Chapter I, Paragraph 173.34.

(d) Inspect the cylinder mounting bracket, bracket hold-down bolts and cylinder holding straps for cracks and deformation, cleanliness, and security of attachment.

(e) In the immediate area where the cylinder is stored or secured, check for evi-

Chapter 9. WINDSHIELDS, ENCLOSURES, AND EXITS

Section 1. PLASTIC WINDSHIELDS AND ENCLOSURES

375. GENERAL. These repairs are applicable to plastic windshields, enclosures, and windows in nonpressurized airplanes. For pressurized airplanes replace or repair plastic elements in accordance with the manufacturer's recommendation.

a. *Types of Plastics.* Two types of plastics are commonly used in transparent enclosures of aircraft. These materials are known as acrylic plastics and polyester plastics.

376. REPLACEMENT PANELS. Use material equivalent to that originally used by the manufacturer of the aircraft for replacement panels. There are many types of transparent plastics on the * market. Their properties vary greatly, particularly in regard to expansion characteristics, brittleness under low temperatures, resistance to discoloration when exposed to sunlight, surface checking, etc. Information on these properties is in MIL-HDBK-17A, Plastics for Flight Vehicles, Part II — Transparent Glazing Materials, available from the Government Printing Office (GPO).* These properties have been considered by aircraft manufacturers in selecting materials to be used in their designs and the use of substitutes having different characteristics may result in subsequent difficulties.

377. INSTALLATION PROCEDURES. When installing a replacement panel, use the same mounting method employed by the manufacturer of the airplane. While the actual installation will vary from one type of aircraft to another, consider the following major principles when installing any replacement panel:

a. *Never force a plastic panel* out of shape to make it fit a frame. If a replacement panel does not fit easily into the mounting, obtain a new replacement or heat the whole panel and reform. When possible, cut and fit a new panel at ordinary room temperature.

b. *In clamping or bolting plastic panels* into their mountings, do not place the plastic under excessive compressive stress. It is easy to develop more than 1,000 pounds per square inch on the plastic by overtorquing a nut and bolt. Tighten each nut to a firm fit, then back off one full turn.

c. *In bolt installations,* use spacers, collars, shoulders, or stopnuts to prevent tightening the bolt excessively. Whenever such devices are used by the airplane manufacturer, retain them in the replacement installation. It is important that the original number of bolts, complete with washers, spacers, etc., be used. When rivets are used, provide adequate spacers or other satisfactory means to prevent excessive tightening of the frame to the plastic.

d. *Mount plastic panels* between rubbed, cork, or other gasket material to make the installation waterproof, to reduce vibration, and to help to distribute compressive stresses on the plastic.

e. *Plastics expand and contract* considerably more than the metal channels in which they are mounted. Mount windshield panels to a sufficient depth in the channel to prevent it from falling out when the panel contracts at low temperatures or deforms under load. When the manufacturer's original design permits, mount panels to a minimum depth of 1 1/8 inch and with a clearance of 1/8 inch between the plastic and the bottom of the channel.

f. *In installations involving bolts or rivets,* make the holes through the plastic oversize 1/8 inch diameter and center so that the plastic will not

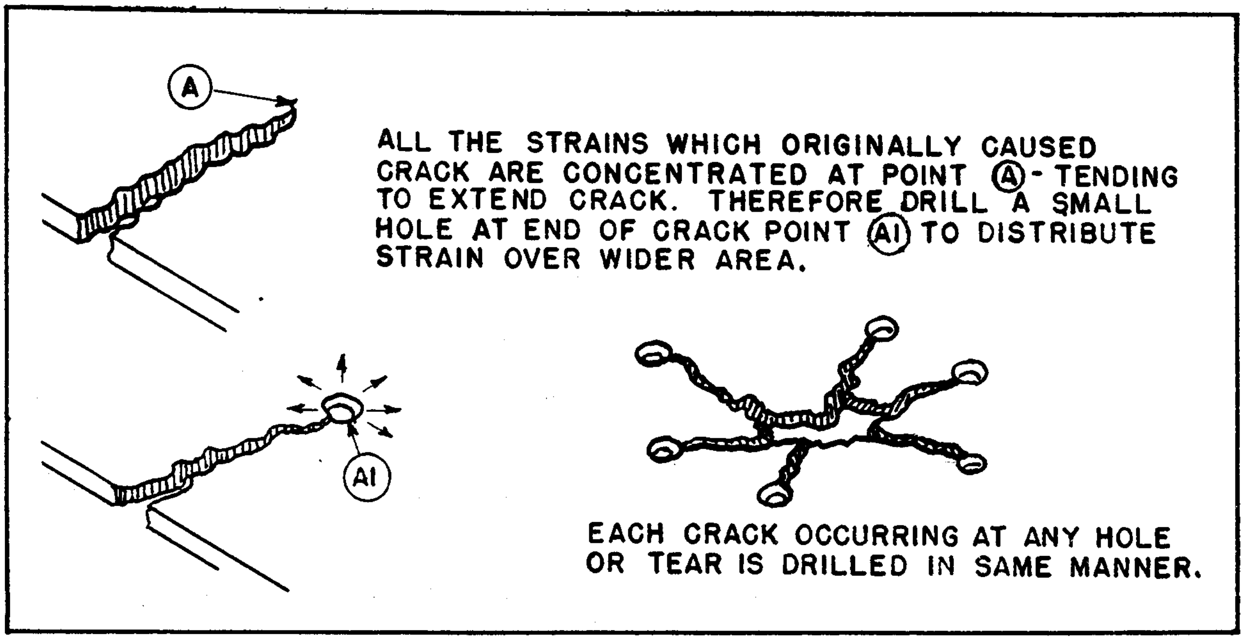

FIGURE 9.1.—Stop-drilling cracks.

bind or crack at the edge of the holes. The use of slotted holes is also recommended.

378. REPAIR OF PLASTICS. Replace extensively damaged transparent plastic rather than repair whenever possible since even a carefully patched part is not the equal of a new section either optically or structurally. At the first sign of crack development, drill a small hole at the extreme ends of the cracks as shown in figure 9.1. This serves to localize the cracks and to prevent further splitting by distributing the strain over a large area. If the cracks are small, stopping them with drilled holes will usually suffice until replacement or more permanent repair can be made. The following repairs are permissible; however, they are not to be located in the pilot's line of vision during landing or normal flight.

a. Surface Patch. If a surface patch is to be installed, trim away the damaged area and round all corners. Cut a piece of plastic of sufficient size to cover the damaged area and extend at least 3/4 inch on each side of the crack or hole. Bevel the edges as shown in figure 9.2. If the section to be repaired is curved, shape the patch to the same contour by heating it in an oil bath at a temperature of 248° to 302° F., or it may be heated on a hotplate until soft.

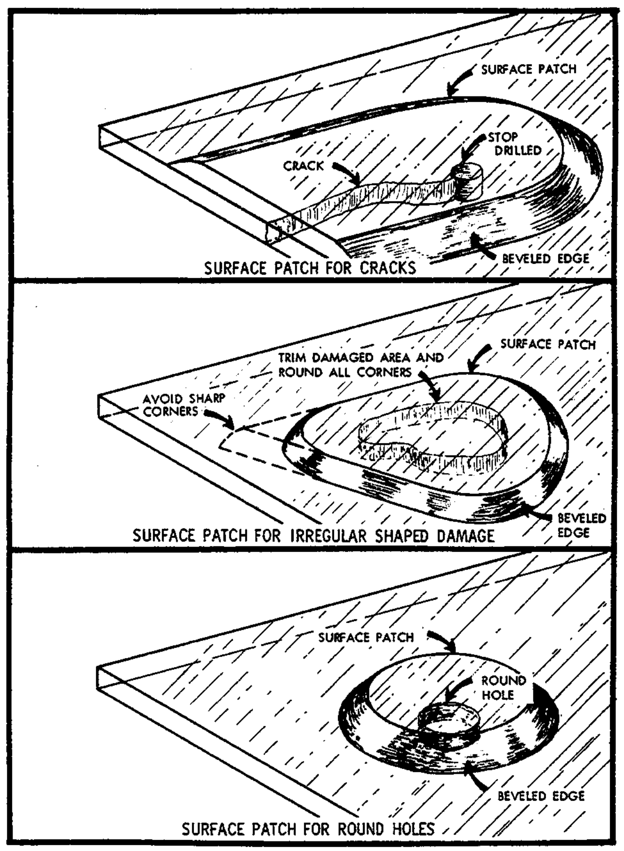

FIGURE 9.2.—Surface patches.

Chapter 10. HYDRAULIC AND PNEUMATIC SYSTEMS

Section 1. HYDRAULIC SYSTEMS

392. GENERAL. Maintain, service, and adjust airplane hydraulic systems in accordance with manufacturers' maintenance manuals and pertinent component maintenance manuals. Certain general principles of maintenance and repair which apply are outlined below.

393. HYDRAULIC LINES AND FITTINGS. Carefully inspect all lines and fittings at regular intervals to insure airworthiness. Investigate any evidence of fluid loss or leaks. Check metal lines for leaks, loose anchorages, scratches, kinks, or other damage. Inspect fittings and connections for leakage, looseness, cracks, burrs, or other damage. Replace or repair defective elements.

a. *Replacement of Metal Lines.* When inspection shows a line to be damaged or defective, replace the entire line or if the damaged section is localized, a repair section may be inserted. In replacing lines, always use tubing of the same size and material as the original line. Use the old tubing as a template in bending the new line, unless it is too greatly damaged, in which case a template can be made from soft iron wire. Soft aluminum tubing (1100, 3003, or 5052) under 1/4-inch outside diameter may be bent by hand. For all other tubing use an acceptable hand or power tube bending tool. Bend tubing carefully to avoid excessive flattening, kinking, or wrinkling. Minimum bend radii values are shown in figure 10.1. A small amount of flattening in bends is acceptable but do not exceed an amount such that the small diameter of the flattened portion is less than 75 percent of the orignial outside diameter. When installing the replacement tubing, line it up correctly with the mating part so that it is not forced into line by means of the coupling nuts.

* **b. *Tube Connections.*** Many tubing connections are made using flared tube ends, and standard connection fittings: AN-818 nut and AN-819 (MS 20819) sleeve. *

In forming flares, cut the tube ends square, file smooth, remove all burrs and sharp edges, and thoroughly clean. The tubing is then flared using the correct 37° aviation flare forming tool for the size of tubing and type of fitting. A double flare is used on soft aluminum tubing 3/8-inch outside diameter and under, and a single flare on all other tubing. In making the connections, use hydraulic fluid as a lubricant and then tighten. Overtightening will damage the tube or fitting, which may cause a failure; under-tightening may cause leakage which could result in a system failure.

Caution

Mistaken use of 45° automotive flare forming tools will result in improper tubing flare shape and angle causing misfit, stress and strain, and probable system failure.

*

FIGURE 10.1.—Tube data.

Dash Nos. Ref	Tubing 00 inches	Wrench torque for tightening AN-818 Nut (pound inch)						Minimum bend radii measured to tubing centerline. Dimension in inches.	
		Aluminum-alloy tubing		Steel tubing		Aluminum-alloy tubing (Flare MS33583) for use on oxygen lines only			
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Alum. Alloy	Steel
-2	1/8	20	30	75	85	--	--	3/8	--
-3	3/16	25	35	95	105	--	--	7/16	21/32
-4	1/4	50	65	135	150	--	--	9/16	7/8
-5	5/16	70	90	170	200	100	125	3/4	1 1/8
-6	3/8	110	130	270	300	200	250	15/16	1 5/16
-8	1/2	230	260	450	500	300	400	1 1/4	1 3/4
-10	5/8	330	360	650	700	--	--	1 1/2	2 3/16
-12	3/4	460	500	900	1000	--	--	1 3/4	2 5/8
-16	1	500	700	1200	1400	--	--	3	3 1/2
-20	1 1/4	800	900	1520	1680	--	--	3 3/4	4 3/8
-24	1 1/2	800	900	1900	2100	--	--	5	5 1/4
-28	1 3/4	--	--	--	--	--	--	--	--
-32	2	1800	2000	2660	2940	--	--	8	7

*

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c. ***Repair of Metal Tube Lines.*** Minor dents and scratches in tubing may be repaired. Scratches or nicks no deeper than 10 percent of the wall thickness in aluminum alloy tubing, that are not in the heel of a bend, may be repaired by burnishing with hand tools. Replace lines with severe die marks, seams, or splits in the tube. Any crack or deformity in a flare is also unacceptable and cause for rejection. A dent less than 20 percent of the tube diameter is not objectionable unless it is in the heel of a bend. Dents may be removed by drawing a bullet of proper size through the tube by means of a length of cable. A severely damaged line should be replaced; however, it may be repaired by cutting out the damaged section and inserting a tube section of the same size and material. Flare both ends of the undamaged and replacement tube sections and make the connection by using standard unions, sleeves, and tube nuts. If the damaged portion is short enough, omit the insert tube and repair by using one union and two sets of connection fittings.

d. ***Replacement of Flexible Lines.*** When replacement of a flexible line is necessary, use the same type, size, and length of hose as the line to be replaced. If the replacement of a hose with swaged-end-type fittings is necessary, obtain a new hose assembly of the correct size and composition. Certain synthetic oils require a specially compounded synthetic rubber hose which is compatible. Refer to the aircraft manufacturer's service information for correct part number for replacement hose. If the fittings on each end are of the collet type or sleeve type, a replacement may be fabricated as shown in figure 10.2. Typical aircraft hose specifications and their uses are shown in figure 10.3. Install hose assemblies without twisting. (See figure 10.4.) Never stretch a hose tight between two fittings as this will result in overstressing and eventual failure. The length of hose should be sufficient to provide about 5 percent to 8 percent slack. Avoid tight bends in flex lines as they may result in failure. Never exceed the minimum bend radii as indicated in figure 10.5.

Teflon hose is used in many aircraft systems because of its superior qualities for certain applications. Teflon is compounded from tetrafluoroethylene resin which is unaffected by fluids normally used in aircraft. It has an operating range of $-65°$ F. to $450°$ F. For these reasons, Teflon is used in hydraulic and engine lubricating systems where temperatures and pressures preclude the use of rubber hose. Although Teflon hose has excellent performance qualities, it also has peculiar characteristics that require extra care in handling. It tends to assume a permanent set when exposed to high pressure or temperature. Do not attempt to straighten a hose that has been in service. Any excessive bending or twisting will cause kinking or weakening of the tubing wall. Replace any hose that shows signs of leakage, abrasion, or kinking. Any hose suspected of kinking may be checked with a steel ball of proper size. Figure 10.6 shows hose and ball sizes. The ball will not pass through if the hose is distorted beyond limits.

If the hose fittings are of the reusable type, a replacement hose may be fabricated as described in figure 10.2. When a hose assembly is removed the ends should be tied as shown in figure 10.7, so that its preformed shape will be maintained. Refer to figure 10.8 for minimum bend radii of Teflon hose.

All flexible hose installations should be supported at least every 24 inches. Closer supports are preferred. They should be carefully routed and securely clamped to avoid abrasion, kinking, or excessive flexing. Excessive flexing may cause weakening of the hose or loosening at the fittings.

e. ***O-Ring Seals.*** A thorough understanding of O-ring seal applications is necessary to determine when replacement must be made. The simplest application is where the O-ring merely serves as a gasket when it is compressed within a recessed area by applying pressure with a packing nut or screw cap. Leakage is not normally acceptable in this type of installation. In other installations the O-ring seals depend primarily upon their resiliency to accomplish their sealing action. When moving parts are involved, minor seepage may be normal and acceptable. A moist surface found on moving parts of hydraulic units is an indication the seal is being properly lubricated. In pneumatic systems, seal lubrication is provided by the installation of a grease-impreg-

FIGURE 11.1.—Wire and circuit protector chart.

Wire AN gauge copper	Circuit breaker amp.	Fuse amp.
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	25 (30)	20
10	35 (40)	30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

Figures in parentheses may be substituted where protectors of the indicated rating are not available.

Basis of chart:

(1) Wire bundles in 135° F. ambient and altitudes up to 30,000 feet.

(2) Wire bundles of 15 or more wires, with wires carrying no more than 20 percent of the total current-carrying capacity of the bundle as given in Specification MIL-W-5088 (ASG).

(3) Protectors in 75 to 85° F. ambient.

* (4) Copper wire Specification MIL-W-5088K or equivalent. *

(5) Circuit breakers to Specification MIL-C-5809 or equivalent.

(6) Fuses to Specification MIL-F-15160 or equivalent.

malfunction can be hazardous, use a switch specifically designed for aircraft service. These switches are of rugged construction and have sufficient contact capacity to break, make, and carry continuously the connected load current. Snap-action design is generally preferred to obtain rapid opening and closing of contacts irrespective of the speed of the operating toggle or plunger, thereby minimizing contact arcing.

b. *Switch Ratings.*

(1) Nominal Rating. The nominal current rating of the conventional aircraft switch is usually stamped on the switch housing and represents the continuous current rating with the contacts closed. Derate switches from their nominal current rating for the following types of circuits:

(a) High In-rush. Circuits containing incandescent lamps can draw an initial current which is 15 times greater than the continuous current. Contact burning or welding may occur when switch is closed.

(b) Inductive. Magnetic energy stored in solenoid coils or relays is released when the control switch is opened and may appear as an arc.

(c) Motors. Direct current motors will draw several times their rated current during starting, and magnetic energy stored in their armature and field coils is released when the control switch is opened.

(2) Switch Selection. Figure 11.2 provides an approximate method for selecting the proper nominal switch rating when the continuous load current is known. The procedure is essentially a derating to obtain reasonable switch efficiency and service life.

(3) Switch Installation. Hazardous errors in switch operation may be avoided by logical and consistent installation. Mount "on-off" two position switches so that the "on" position is reached by an upward or forward movement of the toggle. When the switch controls movable aircraft elements, such as landing gear or

FIGURE 11.2.—Switch derating factors.

Nominal system voltage	Type of load	Derating factor
24 V.D.C.	Lamp	8
24 V.D.C.	Inductive (Relay-Solenoid)	4
24 V.D.C.	Resistive (Heater)	2
24 V.D.C.	Motor	3
12 V.D.C.	Lamp	5
12 V.D.C.	Inductive (Relay-Solenoid)	2
12 V.D.C.	Resistive (Heater)	1
12 V.D.C.	Motor	2

NOTES:

1. To find the nominal rating of a switch to operate a given device, multiply the continuous load current required by the device by the derating factor corresponding to the voltage and type of load.

2. To find the continuous load current that a switch of a given nominal rating will handle efficiently, divide the switch nominal rating by the derating factor corresponding to the voltage and type of load.

flaps, the toggle should move in the same direction as the desired motion. Inadvertent operation of switches can be prevented by mounting suitable guards over the switches.

(4) Relays. Relays are used as a switching device where a weight reduction can be achieved, or to simplify electrical controls. It should be remembered that the relay is an electrically operated switch, and therefore subject to dropout under low system voltage conditions. Concerning contact ratings, the discussion of switch ratings in paragraph 430b(1) is generally applicable to relays.

431.-441. RESERVED.

Section 3. ELECTRIC WIRE

442. GENERAL. Aircraft service imposes severe environmental conditions on electric wire. To assure satisfactory service, inspect the wire at regular intervals for abrasions, defective insulation, condition of terminal posts, and buildup of corrosion * under or around swaged terminals. *

a. *Voltage Drop in Wires.* The voltage drop in the main power wires from the generation source or the battery to the bus should not exceed 2 percent of the regulated voltage, when the generator is carrying rated current or the battery is being discharged at the 5-minute rate. The following tabulation shows the maximum acceptable voltage drop in the load circuits between the bus and the utilization equipment.

FIGURE 11.2a—Tabulation chart.

Nominal system voltage	Allowable voltage drop continuous operation	Intermittent operation
14	0.5	1
28	1	2
115	4	8
200	7	14

b. *Resistance.* The resistance of the current return path through the aircraft structure is always considered negligible. However, this is based on the assumption that adequate bonding of the structure or a special electric current return path has been provided which is capable of carrying the required electric current with a negligible voltage drop. A resistance measurement of .005 ohms from ground point of the generator or battery to ground terminal of any electrical device may be considered satisfactory. Another satisfactory method of determining circuit resistance is to check the voltage drop across the circuit. If the voltage drop does not exceed the limit established by the aircraft or product manufacturer, the resistance value for the circuit may be considered satisfactory. When utilizing the voltage drop method of checking a circuit, maintain the input voltage at a constant value. Figures 11.3 and 11.4 show formulas that may be used to determine resistance in electrical wires.

FIGURE 11.3.—Examples determining voltage drop from electric wire chart (figure 11.7).

Voltage drop	Enter chart (feet)	Amperes	Wire size from chart	Check
1	100	20	No. 6	VD=[2](.000436) (100)(20)=.872
0.5	$\frac{100}{0.5}=200$	20	No. 4	VD=[2](.000274) (100)(20)=.548
4	$\frac{100}{4}=25$	20	No. 12	VD=[2](.00188) (100)(20)=3.76
7	$\frac{100}{7}=14$	20	No. 14	VD=[2](.00299) (100)(20)=5.98

[1]It should be noted that the No. 14 wire should not be used if any portion of its 100-foot length is to be confined in conduit, large bundles, or locations of high ambient temperature, as the intersection of the wire size and current lines fall below curve 1.

[2]Resistance values from figure 11.5.

FIGURE 11.4—Examples determining voltage drop from electric wire chart (figure 11.7).

Voltage drop	Wire	Amperes	Max. length (ft.) from chart at voltage drop indicated	Check
1	No. 10	20	45	VD=[1](.0011) (20)945)=.990
0.5	-----	--	(45)(.5)= 22.5	VD=[1](.0011) (20)(22.5)=.495
4	-----	--	(45)(4)= 180	VD=[1](.0011) (20)(180)=3.96
7	-----	--	(45)(7)= 315	VD=[1](.0011) (20)(315)=6.93

[1]Resistance values from figure 11.5.

FIGURE 11.5.—Copper electric wire current carrying capacity.

*

Wire size	Single wire in free air—maximum amperes	Wire in conduit or bundled—maximum amperes	Maximum resistance—ohms/ 1,000 feet (20° C.)	Nominal conductor area—circular mills	Finished wire weight—pounds per 1,000 feet
AN-20	11	7.5	10.25	1,119	5.6
AN-18	16	10	6.44	1,779	8.4
AN-16	22	13	4.76	2,409	10.8
AN-14	32	17	2.99	3,830	17.1
AN-12	41	23	1.88	6,088	25.0
AN-10	55	33	1.10	10,433	42.7
AN-8	73	46	.70	16,864	69.2
AN-6	101	60	.436	26,813	102.7
AN-4	135	80	.274	42,613	162.5
AN-2	181	100	.179	66,832	247.6
AN-1	211	125	.146	81,807	....
AN-0	245	150	.114	104,118	382
AN-00	283	175	.090	133,665	482
AN-000	328	200	.072	167,332	620
AN-000	380	225	.057	211,954	770

*

FIGURE 11.6—Aluminum electric wire current carrying capacity.

*

Wire size	Single wire in free air—maximum amperes	Wire in conduit or bundled—maximum amperes	Maximum resistance—ohms/ 1,000 feet (20° C.)	Nominal conductor area—circular mills	Finished wire weight—pounds per 1,000 feet
AL-6	83	50	0.641	28,280	....
AL-4	108	66	.427	42,420	....
AL-2	152	90	.268	67,872	....
AL-0	202	123	.169	107,464	166
AL-00	235	145	.133	138,168	204
AL-000	266	162	.109	168,872	250
AL-0000	303	190	.085	214,928	303

*

443. AIRCRAFT ELECTRICAL WIRE. Use aircraft-quality wire. Correct wire selection is dependent upon knowledge of current requirements, operating temperatures, and environmental conditions involved in the particular installation.

a. *Conductors.* Copper conductors are coated to prevent oxidation and to facilitate soldering. Tinned copper or aluminum wire is generally used in installations where operating temperatures do * not exceed 221° F. (105° C.). Aluminum wire shall be restricted to size 6 and larger. Aluminum wire shall neither be directly attached to engine-mounted accessories nor installed in other areas of severe vibration. It shall not be installed where frequent connections and disconnections are required. All installations of aluminum wire shall be relatively permanent. Aluminum wire shall not be used where the length of run is less than 3 feet, in areas where corrosive fumes exist. It is not recommended for use in communication or navigation systems.

Silver coated wire is used where temperatures do not exceed 392° F. (200° C.).

Caution

An inflammability hazard exists when silver or silver plated conductors impressed with direct current potential are saturated with water/glycol solutions. The positive (cathodic) may be of any conductive material. If the anode and cathode are in sufficient proximity to permit current (in the millampere range) to flow through a glycol solution which has contaminated the space between the two conductors, oxidation is rapid and an intensely hot flame appears. This phenomenon is not known to occur when the anode is other than *

* silver or when the impressed voltage is alternating current. Nickel-coated copper wire is used for temperatures up to 500° F. (260° C.).

Nickel-coated wire is more difficult to solder than tinned or silver-coated wire, but with proper techniques, satisfactory connections can be made.

b. *Insulation.* Silicone rubber is rated at 392° F. (200° C.), is (continued on page 181) *

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highly flexible, and self-extinguishing except in vertical runs. Polytetrafluoroethylene (TFE Fluorocarbon) is widely used as high-temperature insulation. It will not burn, but will vaporize when exposed to flame. It is resistant to most fluids. Fluorinated ethylene propolene (FEP Fluorocarbon) is rated at 392° F. (200° C.), but will melt at higher temperatures. Other properties of FEP are similar to TFE.

c. ***Thermal and Abrasion Resistant Materials.*** Glass braid has good thermal and abrasion qualities but moisture absorption is high. Asbestos and other minerals provide high temperature and flame resistance, but are highly absorbent. Moisture absorption is reduced by use of silicone rubber, TFE, or other saturants. Nylon is widely used in low-temperature wires for abrasion and fluid resistance. Polyimide, a new material, has excellent thermal and abrasion resistant characteristics.

d. ***Wire Selection.*** When selecting wire, refer to structural and environmental characteristics. Wire normally used for chassis wiring, in enclosed areas, or in compact wire harnesses protected by molded or braided coverings, usually has low abrasion resistance. Wire used to interconnect units, or in long, open runs in the airframe, is designed to withstand normal aircraft environment without sleeving, jacketing, or other protection. Care must be taken in making all installations because no wire insulation or jacketing will withstand continuous scuffing or abrasion.

* 444. INSTRUCTIONS FOR USE OF ELECTRICAL WIRE CHART.

a. ***To select the correct size*** of electrical wire, two major requirements must be met:

(1) The size must be sufficient to prevent an excessive voltage drop while carrying the required current over the required distance. (See figure 11-2a, Tabulation Chart, for allowable voltage drops.)

(2) The size must be sufficient to prevent overheating of the wire carrying the required current.

b. ***To meet the first requirement of 444a(1)*** in selecting the correct wire size using figure 11-7 or 11-7a, the following must be known:

(1) The wire length in feet.

(2) The number of amperes of current to be carried.

(3) The amount of voltage drop permitted.

(4) Is the current to be carried continuous or intermittent?

c. ***Example No. 1:*** Find the wire size in figure 11-7 using the following known information:

(1) Fifty feet installation.

(2) Twenty ampere current load.

(3) Twenty-eight volt source from bus to equipment.

(4) Continuous current rating operation.

The scale on the left of the chart represents maximum wire length in feet to prevent an excessive voltage drop for a specified voltage source system (e.g., 14V, 28V, 115V, 200V).

The scale (slant lines) on top of the chart represents amperes. The scale at the bottom of the chart represents the size. From the left scale (wire length), find No. 50 under the 28V source column. Follow the horizontal line to the right until it intersects the slant 20 ampere line. At this point drop to the bottom of the chart. The value falls between No. 8 and No. 10 size wires. Select the larger wire size, No. 8. This is the smallest size wire that should be used to avoid an excessive voltage drop of one volt for a 28V system. This example is plotted on the wire chart, figure 11-7.

d. ***The procedures in "c"*** can be used to find the wire size for any continuous or intermittent operation (maximum 2 minutes) voltage (e.g., 14V, 28V, 115V, 200V) indicated on the scale left of the wire chart, figure 11-7 or 11-7a.

e. ***To meet the second requirement of 444a(2)*** in selecting the correct wire size using figure 11-7 or 11-7a, the following must be known:

(1) The number of amperes of current to be carried.

(2) Is the wire to be installed in conduit and/ or bundle on a continuous current rating (curve 1, figure 11-7)?

(3) Is the wire to be installed as a single wire in free air on a continuous current rating (curve 2, figure 11-7)? *

* **(4)** Is the wire used in an intermittent current rating of 2 minutes maximum (curve 3, figure 11-7a)?

f. *Example No. 2:* Find the wire size in figure 11-7 using the following known information.

(1) Fourteen feet installation.

(2) Twenty-eight volt source from bus to equipment.

(3) Continuous current through conduit or bundle.

Find the number 14 under 28 volts source column. Follow the horizontal line to the right until it intersects the slant 20-ampere line. At this point drop to the bottom of the chart. The value falls between No. 16 and No. 14, select the larger size, No. 14. The wire will be placed in conduit, so curve 1 applies. The maximum continuous current for No. 14 wire is 17 amperes.

In this particular case, in order for the wire to carry 20 amperes, the intersection must lie above the rating curve or else the thermal limits of the wire will be exceeded. We must, therefore, increase the wire size to No. 12. This example is plotted on the wire chart figure 11-7.

g. *To find the wire size* for a wire installation run in a conduit and/or bundle (curve 1), use the same procedure and figure 11-7 as above.

h. *To find the wire size* for a wire installation run in an intermittent rating (curve 3), the same procedure applies (except you use the wire chart in figure 11-7a). *

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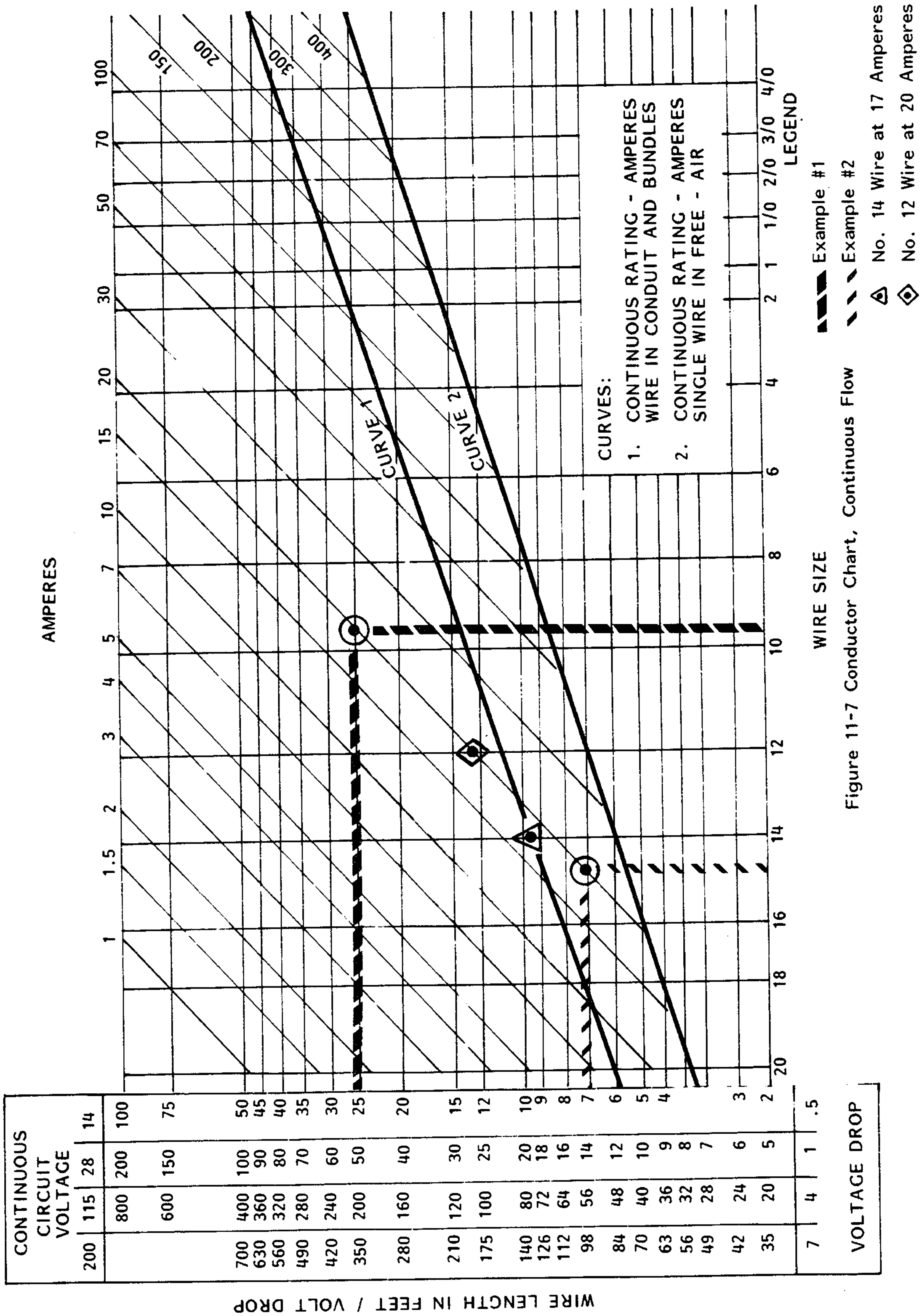

Figure 11-7 Conductor Chart, Continuous Flow

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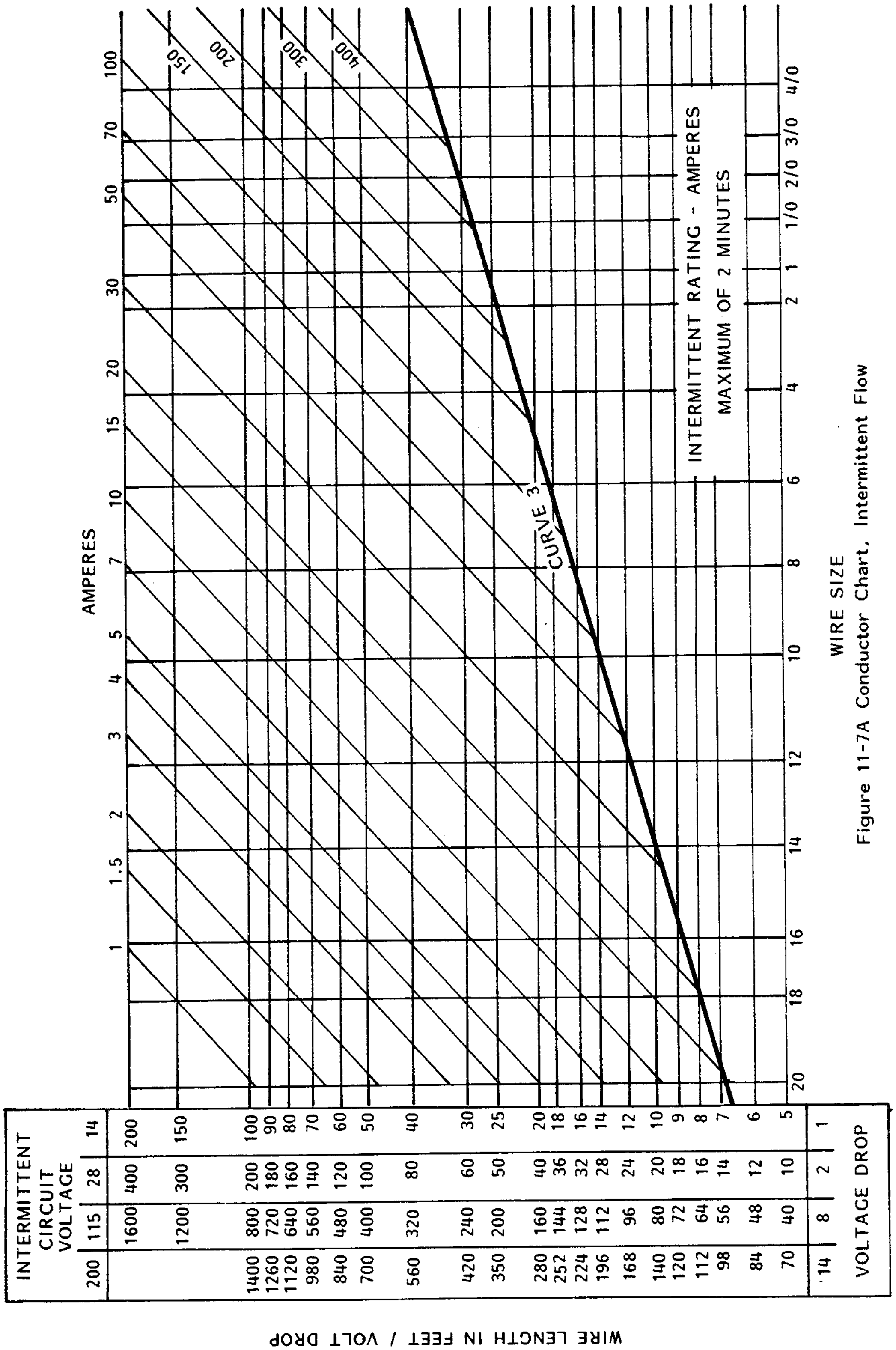

14	28	115	200
200	400	1600	
150	300	1200	
100	200	800	1400
90	180	720	1260
80	160	640	1120
70	140	560	980
60	120	480	840
50	100	400	700
40	80	320	560
30	60	240	420
25	50	200	350
20	40	160	280
18	36	144	252
16	32	128	224
14	28	112	196
12	24	96	168
10	20	80	140
9	18	72	120
8	16	64	112
7	14	56	98
6	12	48	84
5	10	40	70
1	2	8	14

Figure 11-7A Conductor Chart, Intermittent Flow

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*

FIGURE 11.7b.—Wire used in aircraft installations.

Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MIL-W-8777	Silver-coated copper	Silicone rubber, glass braid, polyester braid	600 V.	200° C.	High temperature interconnection. Self-extinguishing. To 155° C. ambient.
MIL-W-8777 MS-27110	Silver-coated copper	Silicone rubber, glass braid, FEP fluorocarbon	600 V.	200° C. 392° F.	Same as MS-26477 but has smooth surface. To 155° C. ambient.
MIL-W-7139 Class 1	Silver-coated copper	TFE fluorocarbon and glass	600 V.	200° C. 392° F.	High temperature interconnection. Self-extinguishing. To 155° C. ambient.
MIL-W-7139 Class 2	Nickel-coated copper	TFE fluorocarbon and glass	600 V.	260° C. 500° F.	Same as Class 1. To 215° C. ambient.
MIL-W-22759/1	Silver-coated copper	TFE tapes/Glass braids	600 V.	200° C.	High temperature.
MIL-W-22759/2	Nickel-coated copper	TFE tapes/Glass braids	600 V.	260° C.	High temperature.
MIL-W-22759/3	Nickel-coated copper	TFE tapes/Glass braids	600 V.	260° C.	High temperature.
MIL-W-22759/4	Silver-coated copper	TFE tapes/Glass braids/FEP jacket	600 V.	200° C.	High temperature.
MIL-W-22759/5	Silver-coated copper	Mineral filled TFE	600 V.	200° C.	Abrasion resistant. Heavy wall.
MIL-W-22759/6	Nickel-coated copper	Mineral filled TFE	600 V.	260° C.	Abrasion resistant. Heavy wall.
MIL-W-22759/7	Silver-coated copper	Mineral filled TFE	600 V.	200° C.	Abrasion resistant. Medium wall.
MIL-W-22759/8	Nickel-coated copper	Mineral filled TFE	600 V.	260° C.	Abrasion resistant. Medium wall.
MIL-W-22759/9	Silver-coated copper	TFE		200° C.	
MIL-W-22759/10	Nickel-coated copper	TFE		260° C.	
MIL-W-22759/11	Silver-coated copper	TFE	600 V.	200° C.	
MIL-W-22759/12	Nickel-coated copper	TFE	600 V.	260° C.	

*

* FIGURE 11.7b.—Wire used in aircraft installations.

Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MIL-W-22759/13	Tin plated copper	FEP/PVF$_2$	600 V.	150° C.	Medium weight.
MIL-W-22759/14	Tin plated copper	FEP/PVF$_2$	600 V.	150° C.	Light weight.
MIL-W-22759/15	Silver coated high strength copper alloy	FEP/PVF$_2$	600 V.	200° C.	Light weight.
MIL-W-22759/16	Tin plated copper	ETFE	600 V.	150° C.	Medium weight. The maximum temperature for MIL-W-22759/16 should be limited to 110° C. conductor temperature and 65° C. ambient temperature. The insulation of MIL-W-22759/16, and other Tefzel insulations should have a nominal wall thickness of at least 10.5 mils.
MIL-W-22759/17	Silver coated high strength copper alloy	ETFE	600 V.	150° C.	Same as MIL-W-22759/16.
MIL-W-22759/18	Tin plated copper	ETFE	600 V.	150° C.	Light weight.
MIL-W-22759/19	Silver coated high strength copper alloy	ETFE	600 V.	150° C.	Light weight.
MIL-W-22759/22	Silver coated high strength copper alloy	TFE	600 V.	200° C.	Light weight.
MIL-W-22759/23	Nickel coated high strength copper alloy	TFE	600 V.	260° C.	Light weight.
MIL-W-25038/1	Nickel coated copper	Inorganic materials	600 V.	260° C.	Fire resistant circuits.
MIL-W-25038/2	Nickel coated copper	Inorganic materials	600 V.	260° C.	Fire resistant circuits.
MIL-W-16878 Type EE	Silver or nickel coated copper	Extruded TFE	1,000 V.	200° C. or 260° C.	Hook-up insulated. High temperature.

*

* FIGURE 11.7b.—Wire used in aircraft installations.

Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MIL-W-81044/6	Tin coated copper	Crosslinked extruded polyalkene	600 V.	-65 to +135	Aerospace electric systems (General purpose aircraft wiring) normal weight.
MIL-W-81044/6B	Tin coated copper	Crosslinked extruded polyalkene	600 V.	-65 to +150	Aerospace electric systems (General purpose aircraft wiring) normal weight.
MIL-W-81044/7B	Silver plated high strength copper alloy	Crosslinked extruded polyalkene	600 V.	-65 to +150	Same as MIL-W-81044/6B.
MIL-W-81044/9B	Tin coated copper	Crosslinked extruded polyalkene	600 V.	-65 to +150	Aerospace electric systems (General purpose aircraft wiring) medium weight.
MIL-W-81044/10B	Silver plated high strength copper alloy	Crosslinked extruded polyalkene	600 V.	-65 to +150	Same as MIL-W-81044/9B.
MIL-W-81044/12B	Tin coated copper	Crosslinked extruded polyalkene	600 V.	-65 to +150	Aerospace electric systems (General electronic wiring) Internal wiring of meters, panels, and electrical and electronic equipment. Light weight.
MIL-W-81044/13B	Silver plated high strength copper alloy	Crosslinked extruded polyalkene	600 V.	-65 to +150	Same as MIL-W-81044/12B.
MIL-W-81381/7E	Silver coated copper	Polyimide/FEP film	600 V.	-65 to +200	Aerospace electric systems (General electronic wiring) Internal wiring of meters, panels, and electrical and electronic equipment. Light weight.
MIL-W-81381/8D	Nickel coated copper	Polyimide/FEP film	600 V.	-65 to +200	Same as MIL-W-81381/7E.

*

* FIGURE 11.7b.—Wire used in aircraft installations. (Continued)

Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MIL-W-81381/11	Silver coated copper	Polyimide/FEP film	600 V.	-65 to +200	Aerospace electric systems (General purpose aircraft wiring) medium weight. The insulation of MIL-W-81381/11, /12 and other Kapton insulations should have a nominal wall thickness of at least 10.0 mils with a minimum of 9.5 mils.
MIL-W-81381/12	Nickel coated copper	Polyimide/FEP film	600 V.	-65 to +200	Same as MIL-W-81381/11.

NOTES:

1. Wire part numbers that are asterisked (*) should not be used without additional mechanical protection, such as an overall shield and/or jacket, or installed within equipment or behind rigid covers.

2. It is recommended that all wire be typed identified along its entire length, specification number, or the aircraft manufacturer's wire part number.

3. Wire Stamping. Old wire stamping methods may not be suitable for wires with thin wall insulation. Wire manufacturer should provide stamping information.

4. Wires should have a 6–inch diameter loop near their connections to (electrical) components to accommodate any wire tensions that result from (aircraft) structural deformations during a crash.

5. Wire added should meet or exceed existing wire specs and should be as direct as possible.

6. All wire connections should be made on a component's least vulnerable side.

7. Electrical wires should be routed along the strongest (aircraft) structural members and should not, in general, traverse areas of anticipated severe structural deformation.

8. Wires that must pass through areas of anticipated structural deformation should be approximately 30% longer than necessary. The extra length should be accumulated in the form of loops or "S" shaped patterns and should be located at the ares of anticipated structural deformation.

9. When wires pass through (aircraft) structural openings or bulkhead holes, these openings/holes should be 8 to 12 times larger than the wire diameter, and appropriate grommets should be provided.

10. Wires should be attached to the aircraft structure with clamps or ties that will fail before breaking the wire.

11. Wire routing should not be near flammable fluid sources. *

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* **445. SPLICES IN ELECTRIC WIRE.** Splicing of electric wire should be kept to a minimum and avoided entirely in locations subject to extreme vibrations. Individual wires in a group or bundle may be spliced provided the completed splice is located so it can be periodically inspected. Stagger splices (see figure 11.8) so the bundle does not become excessively enlarged. Many types of aircraft splice connectors are available for use when splicing individual wires. Use of the self-insulated splice connector is preferred; however, a noninsulated splice connector may be used provided the splice is covered with plastic sleeving which is secured at both ends. Solder splices may be used; however, they are particularly brittle and not recommended. Splices are subject to the following:

a. ***There shall be not more than one splice*** in any one wire segment between any two connectors or other disconnect points, except as allowed by c and g below.

b. ***Splices in bundles*** shall be staggered and shall not increase the size of the bundle so as to prevent the bundle from fitting in its designated space or cause congestion which will adversely affect maintenance.

c. ***Splices shall not be used*** to salvage scrap lengths of wire.

d. ***Splices shall not be used*** within 12 inches of a termination device, except for e below.

e. ***Splices may be used*** within 12 inches of a termination device when attaching to the pigtail spare lead of a potted termination device, or to splice multiple wires to a single wire, or to adjust the wire sizes so that they are compatible with the contact crimp barrel sizes.

f. ***The application*** of splices shall be under design control and shall be authorized by engineering drawings.

g. ***Splices may be used*** to repair manufactured harnesses or installed wiring when approved by engineering.

446. OPEN WIRING. Electric wiring is often installed in aircraft without special enclosing means. This practice is known as open wiring and offers the advantages of ease of maintenance and reduced weight.

a. ***Wire Bundles.*** To simplify maintenance and to minimize the damage that may result from a single fault, limit the number of wires in the run. Shielded wire, ignition wire, and wires which are not protected by a circuit breaker or fuse are usually routed separately. Avoid bending radii less than 10 times the outer diameter of the bundle to prevent excessive stresses on the wire insulation.

b. ***Insulating Tubing.*** Soft insulating tubing (spaghetti) cannot be considered as mechanical protection against external abrasion of wire, since at best it provides only a delaying action. Use conduit or ducting when mechanical protection is needed.

c. ***Clamping of Wire Bundles.*** Use clamps lined with nonmetallic material to support the wire bundle along the run. Tying may be used between clamps, but should not be considered as a substitute for adequate clamping. Adhesive tapes are subject to age deterioration and, *

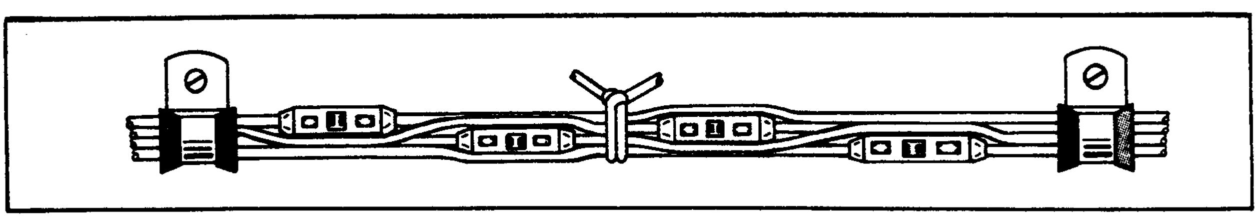

FIGURE 11.8.—Staggered splices in wire bundle.

therefore are not acceptable as a clamping means.

d. Separation from Flammable Fluid Lines. An arcing fault between an electric wire and a metallic flammable fluid line may puncture the line and result in a serious fire. Consequently, make every effort to avoid this hazard by physical separation of the wire from lines or equipment containing oil, fuel, hydraulic fluid, or alcohol. When separation is impractical, locate the electric wire above the flammable fluid line and securely clamp to the structure. In no case, should a wire be supported by a flammable fluid line.

447. HEAT PRECAUTIONS. Separate wires from high temperature equipment, such as resistors, exhaust stacks, heating ducts, etc., to prevent insulation breakdown. Insulate wires that must run through hot areas with a high temperature insulation material such as asbestos, fiberglas, or teflon. Avoid high temperature areas when using cables having soft plastic insulation such as polyethylene because these materials are subject to deterioration and deformation at elevated temperatures. Many coaxial cables have this type of insulation.

448. PROTECTION AGAINST CHAFING. Protect wire and wire groups against chafing or abrasion as damaged insulation may result in short circuits, malfunctions, or inoperative equipment. Support wire bundles using MS-21919 cable clamps as indicated in figure 11.9. When clamped in position, if there is less than 1/4-inch clearance between a bulkhead cutout and the wire bundle, install a suitable grommet as indicated in figure 11.10. The grommet may be cut at 45° angle to facilitate installation provided it is cemented in place and the slot is located at the top of the cutout.

449. STRIPPING INSULATION. Attachment of wire to connectors or terminals requires the removal of insulation to expose the conductors. This practice is commonly known as stripping. When performing the stripping operation, remove no more insulation than is necessary. Stripping may be accomplished in many ways;

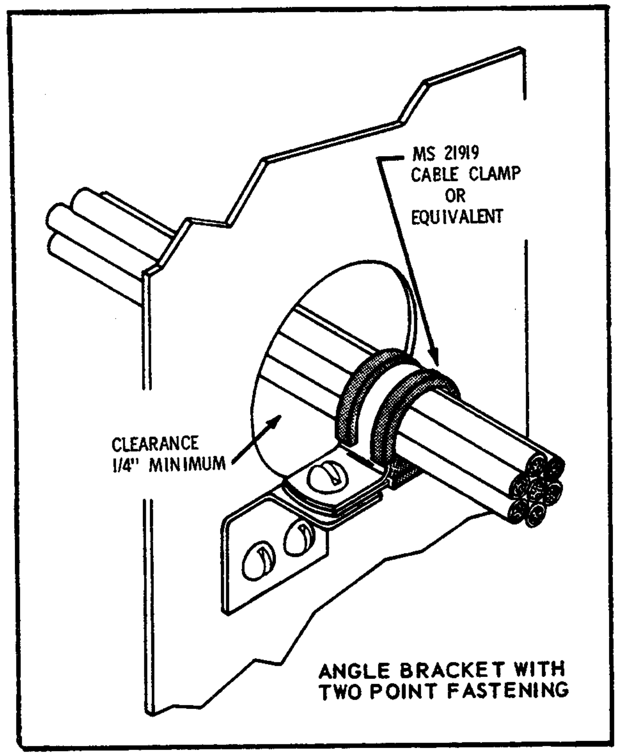

FIGURE 11.9—Cable clamp at bulkhead hole.

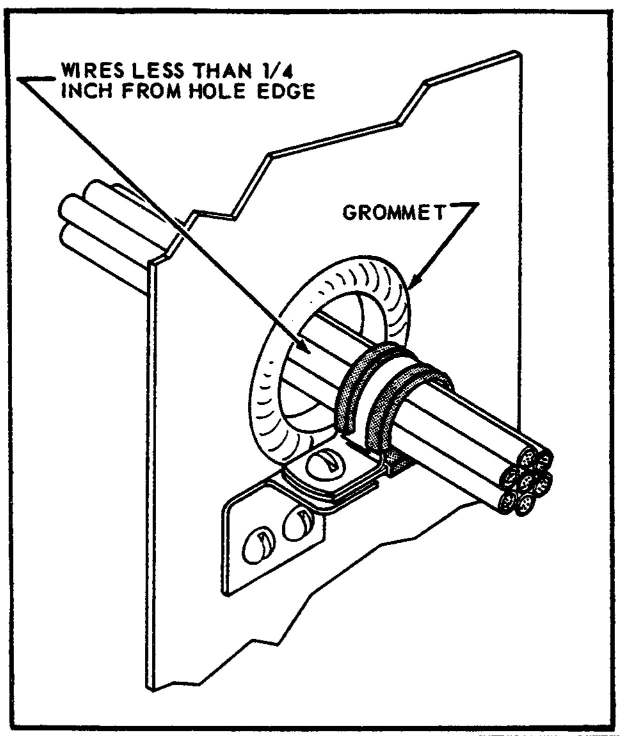

FIGURE 11.10—Cable clamp and grommet at bulkhead hole.

FIGURE 11.11.—Allowable nicked or broken strands.

*

Maximum allowable nicked and broken strands.

Wire Size #	Conductor material	Number of strands per conductor	Total allowable nicked and broken strands
24-14	Copper	19	2 nicked, none broken
12-10	or	37	4 nicked, none broken
8-4	Copper Alloy	133	6 nicked, none broken
2-1		665-817	6 nicked, 2 broken
0-00		1,045-1330	6 nicked, 3 broken
000		1,665-	6 nicked, 4 broken
0000		2,109-	6 nicked, 5 broken
6-000	Aluminum	All numbers of strands	None, None

*

however, the following basic principles should be practiced:

a. ***Make sure all cutting tools*** used for stripping are sharp.

b. ***When using special wire stripping tools,*** adjust the tool to avoid nicking, cutting, or otherwise damaging the strands.

c. ***Damage to wires*** should not exceed the limits specified in figure 11.11.

450. TERMINALS. Terminals are attached to the ends of electric wires to facilitate connection of the wires to terminal strips or items of equipment. The tensile strength of the wire to terminal joint should be at least equivalent to the tensile strength of the wire itself, and its resistance negligible relative to the normal resistance of the wire. Terminals specifically designed for use with the standard sizes of aircraft wire are available through normal supply channels. Haphazard choice of commercial terminals may lead to overheated joints, vibration failures, and corrosion difficulties.

a. ***Solder Terminals.*** For most applications, soldered terminals have been replaced by solderless terminals. The solder process has disadvantages that have been overcome by use of the solderless terminals. A few of these disadvantages are listed as follows:

(1) A more skilled operator is required.

(2) A corrosive flux may be used causing the joint to deteriorate.

(3) Maintenance is extremely difficult.

(4) The wire strands are stiffened by the solder and become more susceptible to breakage due to vibration.

(5) The wire insulation may be charred during the soldering process.

b. ***Solderless Terminals.*** The terminal manufacturer will normally provide a special crimping or swaging tool for joining the solderless terminal to the electric wire. Aluminum wire presents special difficulty in that each individual strand is insulated by an oxide coating. This oxide coating must be broken down in the crimping process and some method employed to prevent its reforming. In all cases, follow the terminal manufacturer's instructions when installing solderless terminals.

* **c.** ***Terminal Strips.*** Wires are usually joined at terminal strips. Use a terminal strip fitted with barriers to prevent the terminals on adjacent studs from contacting each other. Studs must be anchored against rotation. When more than four terminals are to be connected together, use two or more adjacent studs and mount a small metal bus across the studs. In all cases, the current is to be carried by the terminal contact surfaces and not by the stud itself. Replace defective studs with studs of the same size and material as terminal strip studs of the smaller sizes may shear due to overtightening the nut. Assure that the replacement stud is securely mounted in the terminal strip and that the terminal securing nut is tight. Mount terminal strips in such a manner that loose metallic objects cannot fall across the terminals or studs. It is good practice to provide at least one spare stud for future circuit expansion, or in case a stud is broken. *

*Inspect terminal strips which provide connection of radio and electronic systems to the aircraft electrical system for loose connections, metallic objects which may have fallen across the terminal strip, dirt and grease accumulation, etc. Such condition can cause arcing which may result in a fire.

d. ***Terminal lugs.*** Wire terminal lugs shall be used to connect wiring to terminal block studs or equipment terminal studs. No more than four terminal lugs or three terminal lugs and a bus shall be connected to any one stud (total number of terminal lugs per stud includes a common bus bar joining adjacent studs. Four terminal lugs plus a common bus bar thus are not permitted on one stud). When the terminal lugs attached to a stud vary in diameter, the greatest diameter shall be placed on the bottom and smallest diameter on top. Terminal lugs shall be selected with a stud hole diameter which matches the diameter of the stud. Tightening terminal connections shall not deform the terminal lugs of the studs. Terminal lugs shall be so positioned that bending of the terminal lug is not required to remove the fastening screw or nut, and movement of the terminal lugs will tend to tighten the connection.

e. ***Copper terminal lugs.*** Solderless crimp style copper wire terminal lugs shall be used. Terminal lugs shall conform to MIL-T-7928. Spacers or washers are not permitted between the tongues of terminal lugs.

f. ***Aluminum terminal lugs.*** Aluminum terminal lugs conforming to MIL-T-7099 (MS-25435, MS-25436, MS-25437 and MS-25438) shall be crimped to aluminum wire only. the tongue of the aluminum terminal lugs or the total number of tongues of aluminum terminal lugs when stacked, shall be sandwiched between two MS-25440 flat washers when terminated on terminal studs. Spacers or washers are not permitted between the tongues of terminal lugs. Special attention shall be given to aluminum wire and cable installation to guard against conditions that would result in excessive voltage drop and high resistance at junctions that may ultimately lead to failure of the junction. Examples of such conditions are improper installation of terminals and washers, improper torsion ("torquing" of nuts, and inadequate terminal contact areas.

g. ***Class 2 terminal lugs.*** Class 2 terminal lugs conforming to MIL-T-7928 may be used for installation by contractors, provided that in such installations Class 1 terminal lugs are adequate for replacement without rework of installation or terminal lugs. Class 2 terminal lugs shall be the insulated type unless the conductor temperature exceeds 105 degrees C in which case uninsulated terminal lugs shall be used. Parts lists shall indicate the appropriate Class 1 terminal lugs to be used for service replacement of any Class 2 terminal lugs installed.

451. ATTACHMENT OF TERMINALS TO STUDS. Electrical equipment malfunction has frequently been traced to poor terminal connections at terminal boards. Loose, dirty, or corroded contact surfaces will produce localized heating which may ignite nearby combustible materials or overheat adjacent wire insulation to the smoking point.

452. BONDING JUMPER INSTALLATIONS. Make bonding jumpers as short as practicable, and install in such a manner that the resistance of each connection does not exceed .003 ohm. The jumper must not interfere with the operation of movable aircraft elements, such as surface controls, nor should normal movement of these elements result in damage to the bonding jumper.

a. ***Bonding Connections.*** To assure a low-resistance connection, remove nonconducting finishes; such as paint and anodizing films, from the attachment surface to be contacted by the bonding terminal. Do not ground electric wiring directly to magnesium parts.

b. ***Corrosion Prevention.*** Electrolytic action may rapidly corrode a bonding connection if suitable precautions are not taken. Aluminum alloy jumpers are recommended for most cases; however, use copper jumpers to bond together parts made of stainless steel, cadmium plated steel, copper, brass, or bronze. Where contact between dissimilar metals cannot be*

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avoided, the choice of jumper and hardware should be such that corrosion is minimized, and the part likely to corrode would be the jumper or associated hardware. Figures 11.12 through 11.17 show the proper hardware combinations for making a bond connection. At locations where finishes are removed, apply a protective finish to the completed connection to prevent subsequent corrosion.

c. ***Bonding Jumper Attachment.*** Avoid the use of solder to attach bonding jumpers. Bond tubular members by means of clamps to which the jumper is attached. Proper choice of clamp material will minimize the probability of corrosion.

d. ***Ground Return Connection.*** When bonding jumpers carry substantial ground return current, determine that the current rating of the jumper is adequate, and that a negligible voltage drop is produced.

453.-463. RESERVED.

Section 4. WIRE MARKING

464. WIRE IDENTIFICATION. To facilitate installation and maintenance, original wire-marking identification is to be retained. The wire identification marking should consist of a combination of letters and numbers which identify the wire, the circuit it belongs to, its gauge size, and any other information to relate the wire to a wiring diagram. The preferred method is to stamp the identification marking directly on the wire. Place identification markings at each end of the wire and at 12- to 15-inch intervals along the length of the wire. Wires less than 3 inches long need not be stamped. Wire lengths 3 to 7 inches should be stamped at the center. If the outer covering or wire insulation will not stamp easily, insulating tubing may be stamped with the identification mark and installed on the wire. Identification sleeves are normally used for identifying the following types of wire or cable:

a. ***Unjacketed shielded wire.***

b. ***Thermocouple wire.***

c. ***Multiconductor cable.***

d. ***High temperature wire*** with insulation difficult to mark (such as asbestos, teflon, and fiberglas).

(1) Thermocouple wire identification is normally accomplished by means of identification sleeves. As the thermocouple wire is usually of the duplex type (two insulated wires within the same casing), each wire at the termination point bears the full name of the conductor. Thermocouple conductors are alumel, chromel, iron, constantan, and copper.

Caution

Do not use metallic bands in place of insulating sleeves. Any method of marking is satisfactory, provided the identifying symbol is legible and contrasts with the wire insulation or sleeve; however, exercise care when machine marking coaxial cable, as flattening the cable may change its electrical characteristics.

465. SLEEVE SELECTION FOR IDENTIFICATION.

a. ***Flexible vinyl sleeving,*** either clear or opaque, is satisfactory for general use.

b. ***For sleeving exposed to high temperatures*** (over 400° F.), use materials such as silicone rubber or silicone fiberglas.

c. ***Use nylon sleeving*** in areas where resistance to solvent and synthetic hydraulic fluids is necessary. The size of identification sleeving for the various sizes of wire are shown in figure 11.18.

* d. ***Plastic wire sleeving.*** Inspect plastic wire sleeving for damage due to abrasion, solvents, or hydraulic fluids. *

FIGURE 11.18.—Sizes of identification sleeving.

Wire Size		Sleeving Size	
AN	AL	No.	Nominal I.D. (inches)
#24		12	.085
#22		11	.095
#20		10	.106
#18		9	.118
#16		8	.113
#14		7	.148
#12		6	.166
#10		4	.208
#8	#8	2	.263
#6	#6	0	.330
#4	#4	3/8 inch	.375
#2	#2	1/2 inch	.500
#1	#1	1/2 inch	.500
#0	#0	5/8 inch	.625
#00	#00	5/8 inch	.625
#000	#000	3/4 inch	.750
#0000	#0000	3/4 inch	.750

466. IDENTIFICATION OF WIRE BUNDLES AND HARNESSES. Due to complexity of modern aircraft electrical systems, the identification of wire bundles is becoming a common practice. Wire bundle identification may be accomplished by the use of a marked sleeve tied in place or by use of pressure-sensitive tape as indicated in figure 11.19.

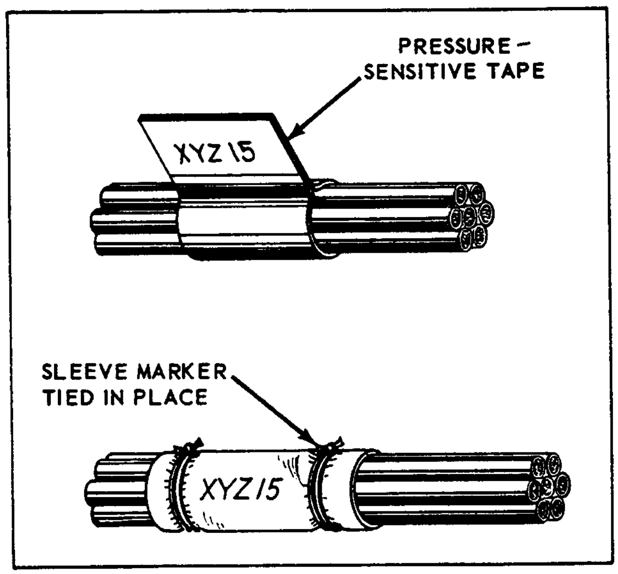

FIGURE 11.19.—Identification of wire bundles and harnesses.

467.-477. RESERVED.

Section 5. CONNECTORS

478. GENERAL PURPOSE CONNECTORS. Connectors (plugs and receptacles) are used to facilitate maintenance when frequent disconnection is required. Since the wires are soldered to the connector inserts, the joints should be individually installed and the wire bundle firmly supported to avoid damage by vibration. Connectors have been particularly vulnerable to corrosion in the past, due to condensation within the shell. Special connectors with waterproof features have been developed and may be used to replace nonwaterproof type plugs in areas where moisture causes a connector problem. Use a replacement connector of the same basic type and design as the connector it replaces. Connectors that are susceptible to corrosion difficulties may be treated with a chemically inert waterproof jelly. When replacing connector assemblies, use the socket-type insert on that half which is live or "hot" after the connector is disconnected to prevent unintentional grounding.

479. TYPES OF CONNECTORS. Connectors are identified by AN numbers and are divided into types and classes with manufacturer's variations in each type and class. The manufacturer's variations are differences in appearance and in the method of meeting the specification; however, they do not preclude mating plugs and receptacles of different manufacturers. There are six basic types of AN connectors used in aircraft which are further broken down into five classes as indicated in figures 11.20 and 11.21. Each class of connector has slightly different construction characteristics which are noted as follows: Classes A, B, C, and D are made of aluminum; Class K is made of steel.

Class A—Solid one-piece back shell general purpose connector.

Class B—Connector back shell separates into two parts lengthwise. Use primarily where it is important that the soldered connectors are readily accessible. The back shell is held together by a threaded ring or by screws.

Class C—A pressurized connector with inserts that are not removable. Looks like a Class A connector but the inside sealing arrangement is sometimes different and is used on walls of bulkheads of pressurized equipment.

Class D—Moisture and vibration resisting connector which has a sealing grommet in the back shell. Wires are threaded through tight fitting holes in the grommet, thereby sealing against moisture.

Class K—A fireproof connector used in areas where it is vital that the electric current is not interrupted, even though connector may be exposed to continuous open flame. Wires are crimped to the pin or socket contacts and the shells are made of steel. This class of connectors is normally longer than the other classes of connectors.

* NOTE: Inspect connectors for loose soldered connections, proper insulation of metallic parts, and fraying of wires in the plug and receptacle inserts. *

480. ARMY/NAVY (AN) CONNECTOR IDENTIFICATION. Code letters and numbers are marked on the coupling ring or shell to identify the connector. This code provides all the information necessary to obtain the correct replacement for a defective or damaged part. To facilitate ready identification the code found on a typical connector (as shown in figure 11.22) is explained as follows:

a. ***The letters AN*** indicate the connector was made to a government standard.

b. ***Type 3106*** indicates this is a straight plug.

c. ***Letter A*** indicates this is a general purpose connector with a solid back shell.

d. ***Number 18*** indicates the size of the coupling. This size is determined in 1/16-inch increments. Therefore, the size of the plug in the example is 1 1/8 inch.

to the base compound and includes the time expended during the mixing and application processes. Mixed compounds that are not to be used immediately must be cooled and thawed quickly to avoid wasting the short working life. Chilled compounds should be thawed by blowing compressed air over the outside of the container. Normally the compound will be ready for use in 5 to 10 minutes.

CAUTION

Do not use heat or blow compressed air into the container when restoring to working temperature.

483. POTTING CONNECTORS. Connectors that have been potted primarily offer protection against concentration of moisture in the connectors. A secondary benefit of potting is the reduced possibility of breakage between the contact and wire due to vibration.

Solder wires to all contacts of the connector prior to the application of the potting compound. Wires that are not to be used should be long enough to permit splicing at a later date. Identify the wires not used as shown in figure 11.23 and cap the cut ends with potting compound prior to securing to the wire bundle. After the soldering operation, scrape off the resin and wash the connector with clean stoddard solvent, brushing vigorously. Rinse the areas to be potted with methylene chloride and complete the potting operation within 2 hours after this cleaning. Allow the potting com-

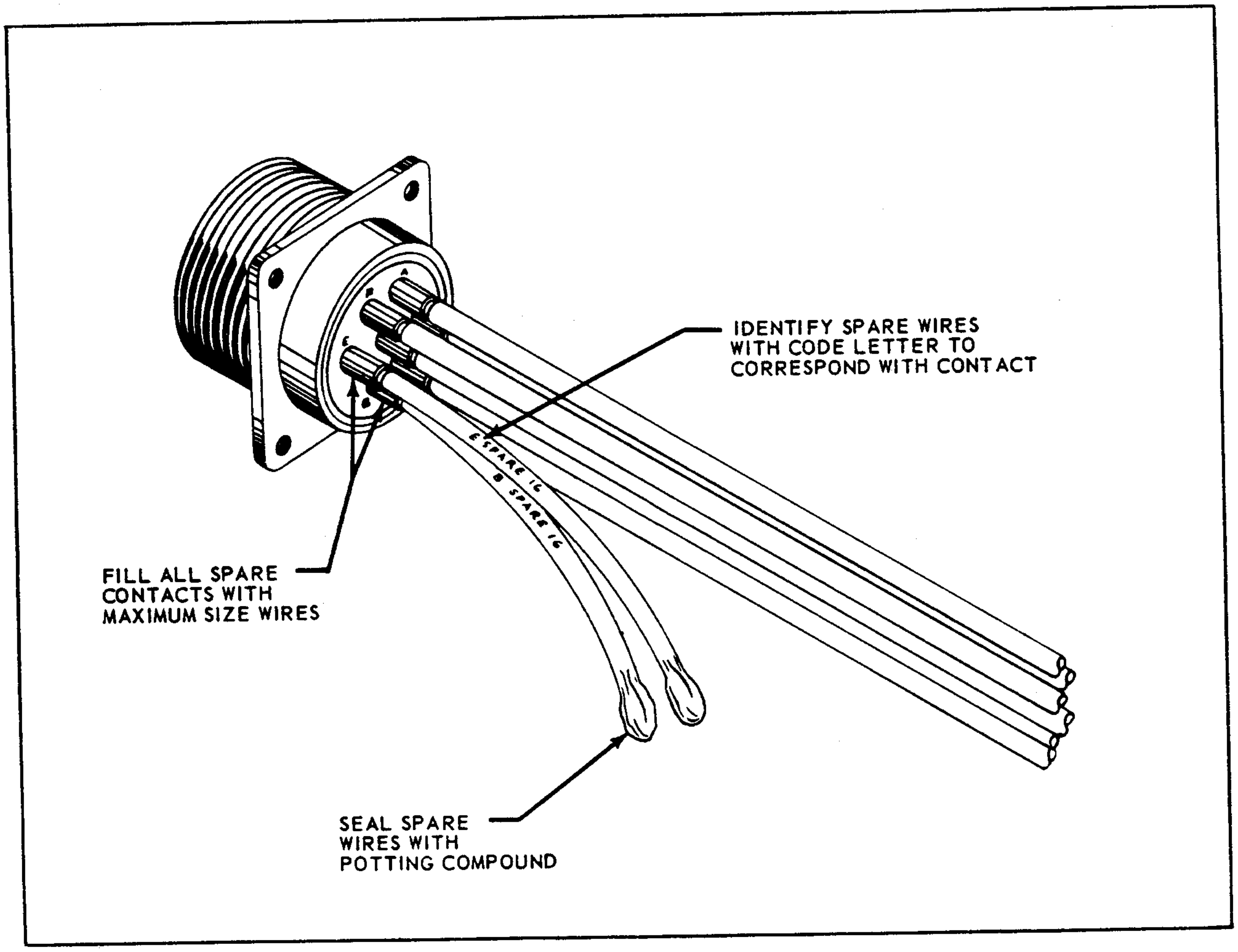

FIGURE 11.23.—Spare wires for potting connector.

pound to cure for 24 hours at a room temperature of 70 to 75° F. or carefully place in a drying oven at 100° F. for 3 to 4 hours.

484. THROUGH BOLTS. Through bolts are sometimes used to make feeder connections through bulkheads, fuselage skin, or firewalls. Mount through bolts in such a manner that they are mechanically secure and independent of the terminal nuts. Provide sufficient cross section to insure adequate conductivity against overheating and enough contact area to minimize voltage drop. Mechanically secure such bolts independent of the terminal mounting nuts, taking particular care to avoid dissimilar metals among the terminal hardware. During inspection, pay particular attention to the condition of the insulator plate or spacer and the insulating boot that covers the completed terminal assembly.

* "485. [Transferred to paragraph 450c.] — Change 3" *

486.—496. RESERVED.

Section 6. CONDUITS

* **497. GENERAL.** Conduit is manufactured in metallic and nonmetallic materials and in both rigid and flexible forms. Primarily its purpose is for mechanical protection of the cable within. Inspect conduit for proper end fittings, absence of abrasion at the end fittings, and proper clamping. Inspect for distortion, adequate drain points which are free of dirt, grease, or other obstructions, and freedom from abrasion or damage due to moving objects such as aircraft control cables or shifting cargo. *

498. SIZE OF CONDUIT. When selecting conduit size for a specific wire bundle application, it is common practice to allow for ease in maintenance and possible future circuit expansion by specifying the conduit inner diameter about 25 percent larger than the maximum diameter of the wire bundle. The nominal diameter of rigid metallic conduit is the O.D. Therefore, to obtain the I.D., subtract twice the tube wall thickness.

499. CONDUIT FITTINGS. From the abrasion standpoint, conduit is vulnerable at its ends. Affix suitable fittings to conduit ends in such a manner that a smooth surface comes in contact with wire within. When fittings are not used, flare the end of the conduit to prevent wire insulation damage. Support the conduit using clamps along the conduit run.

500. CONDUIT INSTALLATION. Many of the past troubles with conduit can be avoided by proper attention to the following details:

a. ***Do not locate conduit*** where passengers or maintenance personnel might use it as a handhold or footstep.

b. ***Provide drainholes*** at the lowest point in a conduit run. Drilling burrs should be carefully removed.

c. ***Support conduit*** to prevent chafing against structure and to avoid stressing its end fittings.

501. RIGID CONDUIT. Repair conduit sections that have been damaged to preclude injury to the wires or wire bundle which may consume as much as 80 percent of the tube area. Minimum acceptable tube bend radii for rigid conduit is shown in figure 11.24. Kinked or wrinkled bends in rigid conduits are not considered acceptable. Tubing bends that have been flattened into an ellipse and the minor diameter is less than 75 percent of the nominal tubing diameter is not considered satisfactory because the tube area will have been reduced at least 10 percent. Carefully deburr tubing that has been formed and cut to final length to prevent wire insulation damage. When installing replacement tube sections with fittings at both ends, exercise care to eliminate mechanical strain.

502. FLEXIBLE CONDUIT. Flexible aluminum conduit conforming to Specification MIL-C-6136 is available in two types; Type I, Bare Flexible Conduit, and Type II, Rubber Covered Flexible Conduit. Flexible brass conduit conforming to Specification MIL-C-7931 is available and normally used instead of flexible aluminum where necessary to minimize radio interference. Flexible conduit may be used where it is impractical to use rigid conduit such as areas that have

FIGURE 11.24.—Bend radii for rigid conduit.

Nominal tube O.D.	Minimum bend radii (inches)
1/8	3/8
3/16	7/16
1/4	9/16
3/8	15/16
1/2	1 1/4
5/8	1 1/2
3/4	1 3/4
1	3
1 1/4	3 3/4
1 1/2	5
1 3/4	7
2	8

motion between conduit ends or where complex bends are necessary. The use of transparent adhesive tape is recommended when cutting flexible tubing with a hacksaw to minimize fraying of the braid. Center the tape over the cut reference mark and saw through the tape. After cutting the flexible conduit, remove the transparent tape, trim the frayed ends of the braid, remove burrs from inside the conduit, and install coupling nut and ferrule. Minimum acceptable bending radii for flexible conduit is shown in figure 11.25.

FIGURE 11.25.—Minimum bending radii for flexible aluminum or brass conduit.

Nominal I.D. of conduit (inches)	*Minimum bending radius inside (inches)*
3/16	2 1/4
1/4	2 3/4
3/8	3 3/4
1/2	3 3/4
5/8	3 3/4
3/4	4 1/4
1	5 3/4
1 1/4	8
1 1/2	8 1/4
1 3/4	9
2	9 3/4
2 1/2	10

503.-513. RESERVED.

to high temperatures. Insulate wires that must be run through hot areas with a material such as asbestos, fiberglass, or an equivalent high temperature-resistant product. Wherever possible, keep wires separated from high-temperature equipment; and when replacing wires, do not use low-temperature insulated wires to replace high-temperature insulated wires.

f. *Wiring Precautions.* Maintain a minimum clearance of 3 inches from any control cable. When this clearance cannot be maintained, install a mechanical guard. When wiring is run parallel to combustible fluid or oxygen lines, maintain as much separation as possible. Locate wires above or on a level with the fluid lines and, wherever possible, maintain a minimum separation of 6 inches. Where the separation is 1/2 inch to 2 inches, install clamps as shown in figure 11.30 to maintain separation. These clamps are not to be used as a means of supporting the wire bundle. Install additional clamps to support the wire bundle and fasten the clamps to the same structure used to support the fluid line to prevent relative motion. Maintain a minimum separation of at least 1/2 inch between plumbing lines and any wire.

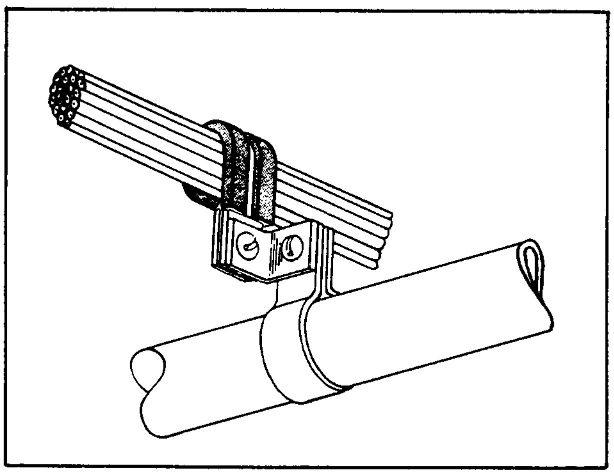

FIGURE 11.30.—Separation of wires from plumbing lines.

518. CLAMPING. Support wires and wire bundles using clamps meeting Specification MS-21919. Exercise care to assure the wire is not pinched when installing clamps to support electrical wiring as shown in figures 11.31 through 11.34. Whenever practical, rest the back of the clamp against a structural member. Install clamps in such manner that the electrical wires do not come in contact with other parts of the aircraft when subjected to vibration. Leave sufficient slack between the last clamp and the electrical equipment to prevent strain at the terminal and to minimize adverse effects on shockmounted equipment. Where wires or wire bundles pass through bulkheads or other structural members, provide a grommet or suitable clamp to prevent abrasion.

*__518-1. WIRE AND CABLE CLAMPS.__ Inspect wire and cable clamps for proper tightness. Where cables pass through structure or bulkheads, inspect for proper clamping or grommets. Inspect for sufficient slack between the last clamp and the electronic equipment to prevent strain at the cable terminals and minimize adverse effects on shock mounted equipment. *

519. TIES AND LACING. Ties, lacing, and straps are used to secure wire groups or bundles, to provide ease of maintenance, inspection, and installation. Cord meeting Specification MIL-C-5649 and twine meeting Specification JAN-T-713 are suitable for lacing or tying wires. In lieu of applying ties, straps meeting Specification MS-17821 or MS-17822 may be used in areas where the temperature does not exceed 120° C. or where the wiring can be damaged by operating units if the strap fails.

a. *Lacing.* Lace wire groups or bundles inside junction boxes or other enclosures. Single cord-lacing method shown in figure 11.35 may be used for wire groups of bundles 1 inch in diameter or less. The recommended knot for starting the single cord-lacing method is a clove hitch secured by a double-looped overhand knot as shown in step a of figure 11.35. Used the double cord-lacing method on wire bundles 1 inch in diameter or larger as shown in figure 11.36. When using the double cord-lacing method, employ a bowline on a bight as the starting knot. Reference step a of figure 11.36.

b. *Tying.* Use wire group or bundle ties where the supports for the wire are more than 12 inches apart. A tie consists of a clove hitch around the wire group or bundle secured by a square knot as shown in figure 11.37.

* **520. INSULATION TAPE.** Insulation tape shall be of a type suitable for the application, or as called out for the specific use. Insulation tape shall be used primarily as a filler under clamps and as secondary support. Nonadhesive tape may be used as a wraparound wiring for additional protection, such as in wheel wells. All tape shall have the ends tied or otherwise suitably secured to prevent unwinding. Tape used for protection shall be applied so that overlapping layers shed liquids, and shall be provided with drainage holes at all trap points, and at each low point between clamps. Plastic tapes which absorb moisture, or which have volatile plasticizers that produce chemical reactions with other wiring shall not be used. (Reference: MIL-W-5088K). *

521.-530. RESERVED.

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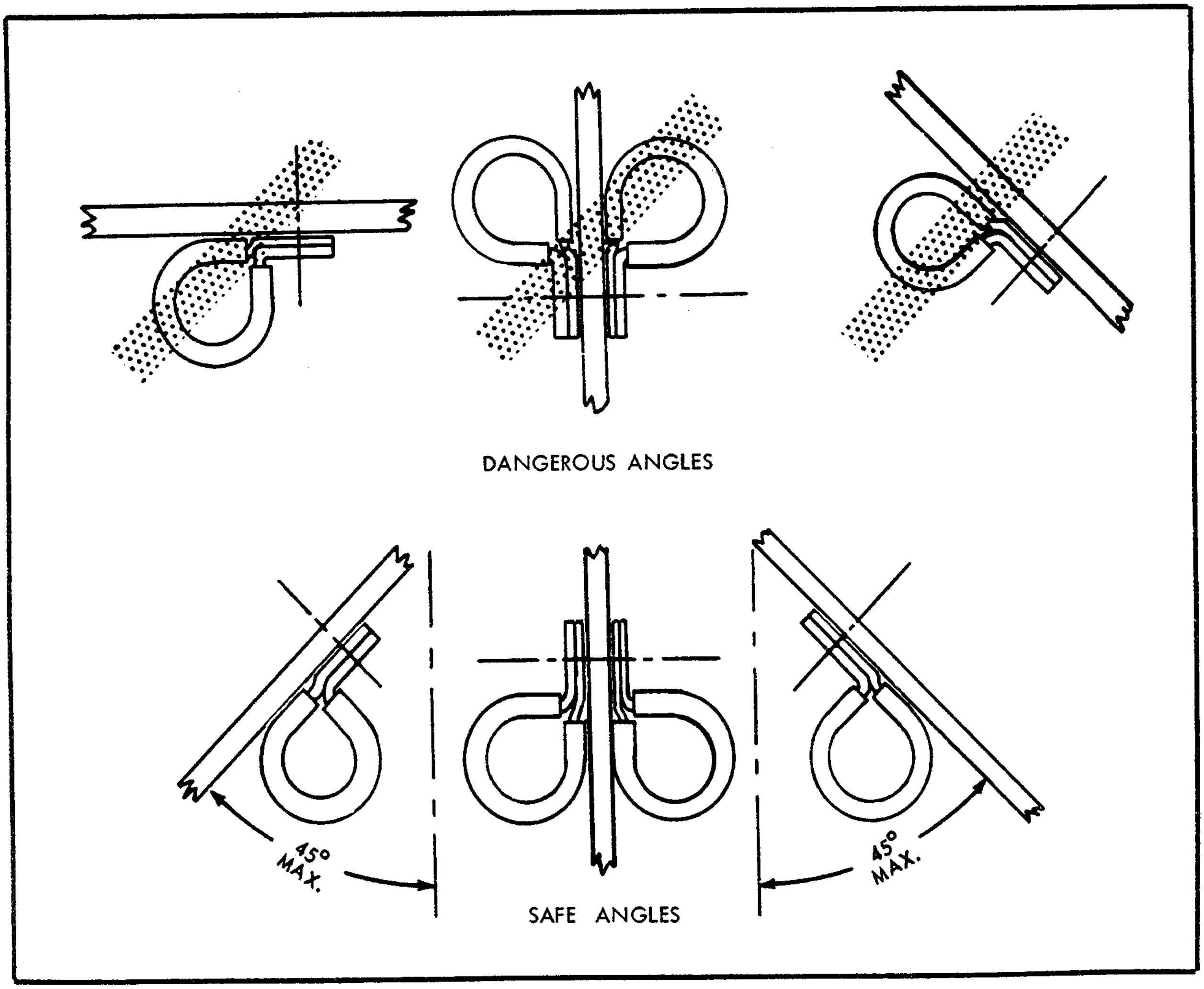


FIGURE 11.31.—Safe angle for cable clamps.

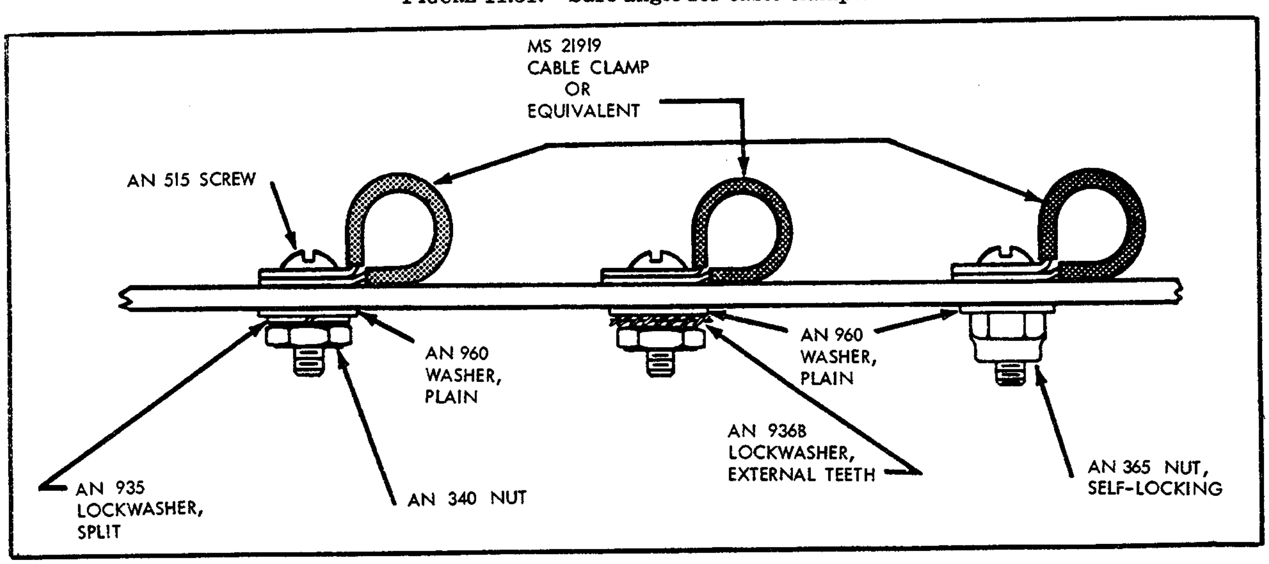


FIGURE 11.32.—Typical mounting hardware for MS-2919 cable clamps.

FIGURE 11.39.—Sulfuric acid temperature correction.

Electrolyte temperature		Points to be subtracted or added to specific gravity readings
°C.	°F.	
60	140	+24
55	130	+20
49	120	+16
43	110	+12
38	100	+ 8
33	90	+ 4
27	80	0
23	70	− 4
15	60	− 8
10	50	−12
5	40	−16
− 2	30	−20
− 7	20	−24
−13	10	−28
−18	0	−32
−23	−10	−36
−28	−20	−40
−35	−30	−44

536. CHECKING NICKEL-CADMIUM BATTERIES. The state of charge of a nickel-cadmium battery cannot be determined by measuring the specific gravity of the electrolyte with a hydrometer as the electrolyte specific gravity does not change with the state of charge. The only accurate way to determine the state of charge of a nickel-cadmium battery is by a measured discharge. After the battery has been fully charged and allowed to stand for at least 2 hours, the fluid level may be adjusted, if necessary, using distilled or demineralized water. Because the fluid level varies with the state of charge, water should never be added while the battery is installed in the aircraft. Overfilling the battery will result in electrolyte spewage during charging. This will cause corrosive effects on the cell links, self discharge of the battery, dilution of the electrolyte density, and possible blockage of the cell vents and eventual cell rupture.

CAUTION

Servicing equipment used for lead-acid batteries is not to be used for servicing nickel-cadmium batteries as acid is detrimental to the proper functioning of a nickel-cadmium battery.

537. ELECTROLYTE CORROSION. Electrolyte spillage or leakage may result in serious corrosion of the nearby structure or control elements as both sulfuric acid and potassium hydroxide are actively corrosive. Electrolyte may be spilled during ground servicing, leaked when cell case rupture occurs, or sprayed from cell vents due to excessive charging rates. If the battery is not case enclosed, properly treat structural parts near the battery which may be affected by acid fumes. Treat all case and drain surfaces which have been affected by electrolyte with a solution of sodium bicarbonate (for acid electrolyte) or boric acid, vinegar, or a 3 percent solution of acetic acid for potassium hydroxide electrolyte.

CAUTION

Serious burns will result if the electrolyte comes in contact with any part of the body. Use rubber gloves, rubber apron, and protective goggles when handling electrolyte. If sulphuric acid is splashed on the body neutralize with a solution of baking soda and water, and shower or flush the affected area with water. For the eyes, use an eye fountain and flush with an abundance of water.

If potassium hydroxide contacts the skin, neutralize with 3 percent acetic acid, vinegar, or lemon juice, and wash with water.

For the eyes, wash with a weak solution of boric acid or a weak solution of vinegar and flush with water.

538. NOXIOUS FUMES. When charging rates are excessive, the electrolyte may boil to the extent that fumes containing droplets of the electrolyte are emitted through the cell vents. These fumes from lead-acid batteries may become noxious to the crewmembers and passengers; therefore, thoroughly check the venting system. Nickel-cadmium batteries will emit gas near the end of the charging process and during overcharge. The battery vent system in the aircraft should have sufficient air flow to prevent this explosive mixture from accumulating. It is often advantageous to install a jar in the battery vent discharge system serviced with an agent to neutralize the corrosive effect of battery vapors.

539. INSTALLATION PRACTICES.

a. Clean the external surface of the battery prior to installation in the aircraft.

b. *When replacing lead-acid batteries* with nickel-cadmium batteries, neutralize the battery box or compartment and thoroughly flush with clear water and dry. Acid residue can be detrimental to the proper functioning of a nickel-cadmium battery.

c. *Check the condition* of the vent system.

d. *When installing batteries* in an aircraft, exercise care to prevent inadvertent shorting of the battery terminals. Serious damage to the aircraft structure can be sustained by the resultant high discharge of electrical energy. This condition may normally be avoided by insulating the terminal posts during the installation process.

e. *Assure the battery holddown devices* are secure but not so tight as to exert excessive pressure which may cause the battery to buckle causing internal shorting of the battery.

f. *If a quick disconnect type* of battery connector which prohibits crossing the battery lead is not employed, assure that the aircraft wiring is connected to the proper battery terminal. Reverse polarity in an electrical system can seriously damage a battery. Assure battery cable connections are tight to prevent arcing or a high resistance connection.

* 540. AIRCRAFT BATTERY INSPECTION.

a. *Inspect battery sump jar* and lines for condition and security.

b. *Inspect battery terminals* and quick-disconnect plugs and pins for evidence of corrosion and pitting, arcing, and burns. Clean as required.

c. *Inspect battery drain* and vent lines for restriction, deterioration, and security. *

541.-552. RESERVED.

Section 3. REPAIR OF METAL PROPELLERS

583. GENERAL. Reject damaged blades with model numbers which are on the manufacturer's list of blades that cannot be repaired. Follow manufacturer's recommendations in all cases, and make repairs in accordance with latest techniques and best industry practices.

584. STEEL BLADES. Due to the critical effects of surface injuries and their repair on the fatigue life of steel blades, all repairs must be made in accordance with the manufacturer's instructions.

585. ALUMINUM PROPELLER REPAIRS. Aluminum-alloy propellers and blades with dents, cuts, scars, scratches, nicks, leading-edge pitting, etc., may be repaired, provided the removal or treatment does not materially affect the strength, weight, or performance of the blade. Remove these damages or otherwise treat as explained below unless contrary to manufacturer's instructions or recommendations. More than one injury is not sufficient cause alone for rejection of a blade. A reasonable number of repairs per blade may be made and not necessarily result in a dangerous condition, unless their location with respect to each other is such to form a continuous line of repairs that would materially weaken the blade. Suitable sandpaper or fine-cut files may be used for removing the necessary amount of metal. In each case, the area involved will be smoothly finished with No. 00 sandpaper or crocus cloth, and each blade from which any appreciable amount of metal has been removed will be properly balanced before it is used. Etch suspected cracks and all repairs as discussed in paragraph 605. To avoid removal of an excessive amount of metal, local etching should be accomplished at intervals during the process of removing suspected cracks. Upon completion of the repair, carefully inspect the entire blade by etching or anodizing. Remove all effects of the etching process with fine emery paper. Blades identified by the manufacturer as being cold-worked (shot-blasted or cold-rolled) may require peening after repair. Accomplish repair and peening operations on this type of blade in accordance with the manufacturer's instructions. However, it is not permissible in any case to peen down the edges of any injury wherein the operation will lap metal over the injury.

a. ***Round out nicks, scars, cuts, etc.,*** occurring on the leading edge of aluminum alloy blades as shown in figure 12.2 (view B). Blades that have the leading edges pitted from normal wear in service may be reworked by removing sufficient material to eliminate the pitting. In this case, remove the metal by starting well back from the edge, as shown in figure 12.3, and working forward over the edge in such a way that the contour will reman substantially the same, avoiding abrupt changes in contour or blunt edges. Trailing edges of blades may be treated in substantially the same manner. On the thrust and camber face of blades, remove the metal around any dents, cuts, scars, scratches, nicks, longitudinal surface cracks, and pits to form shallow saucer-shaped depressions as shown in figure 12.2 (view C). Exercise care to remove the deepest point of the injury and also remove any raised metal around the edges of the injury as shown in figure 12.2 (view A). For repaired blades, the permissible reduction in width and thickness for minimum original dimensions, allowed by the blade drawing and blade manufacturing specifications are shown in figure 12.4 for locations on the blade from the shank to 90 percent of the blade
* radius. Beyond the 90 percent blade radius point, the blade width and thickness may be modified as per manufacturer's instructions. *

b. ***Shortening blades.*** When the removal or treatment of defects on the tip necessitates shortening a blade, shorten each blade used

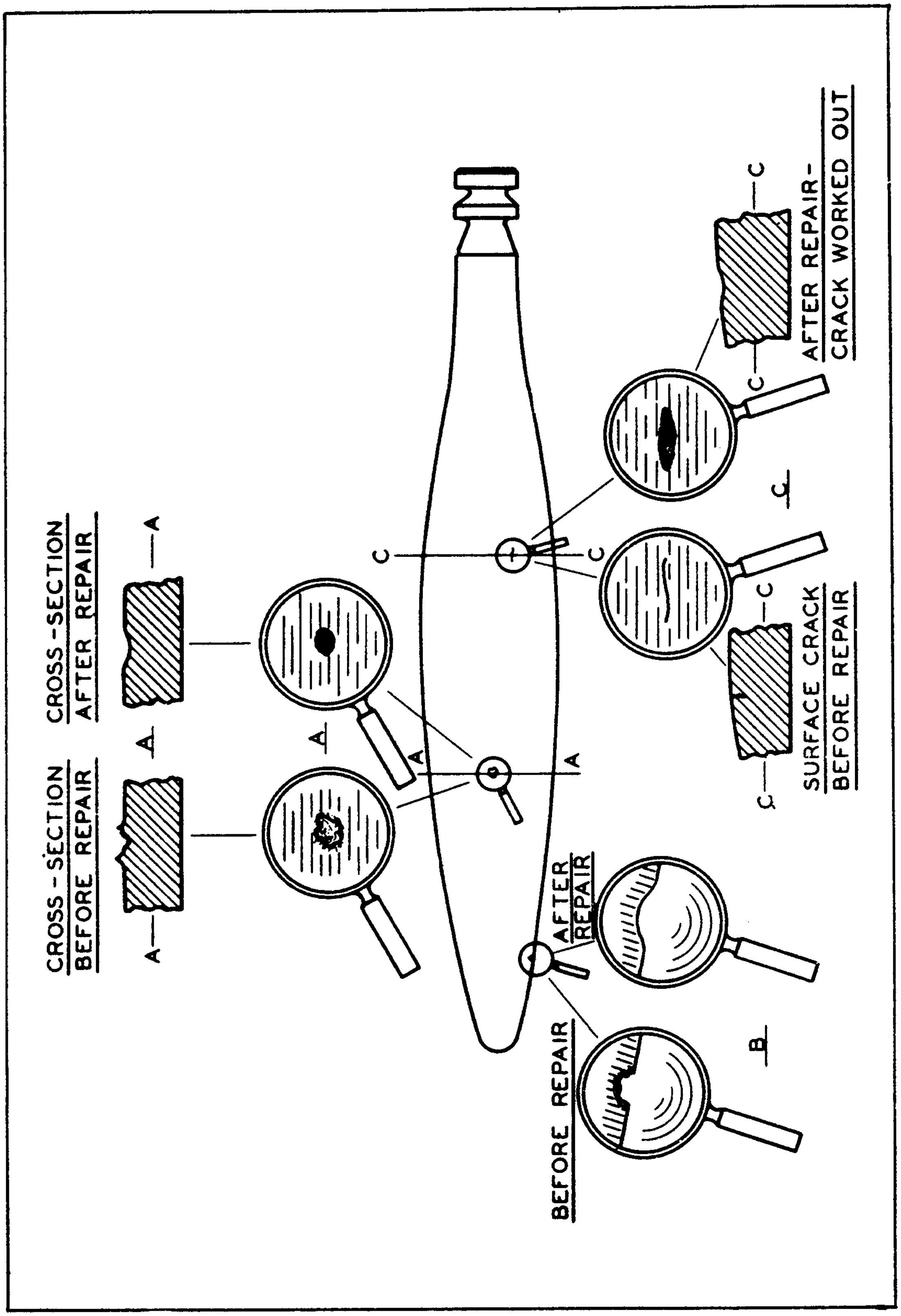


FIGURE 12.2.—Method of repairing surface cracks, nicks, etc., on aluminum alloy propellers.

the shanks (roots or hub ends) of adjustable pitch blades.

a. ***Suspected cracks or defects*** should be repeatedly local etched until their nature is determined. With a No. 00 sandpaper, or fine crocus cloth, clean and smooth the area containing the apparent crack. Apply a small quantity of caustic solution to the suspected area with a swab or brush. After the area is well darkened, thoroughly wipe it with a clean (dampened) cloth. Too much water may entirely remove the solution from a crack and spoil the test. If a crack extending into the metal exists, it will appear as a dark line or mark, and by using a magnifying glass, small bubbles may be seen forming in the line or mark. Immediately upon completion of the final checks, remove all traces of the caustic solution by use of the nitric acid solution. Wash the blade thoroughly with clean (fresh) water.

b. ***The chromic acid anodizing process*** is superior to caustic etching for the detection of cracks and flaws and should therefore be used, whenever it is available, for general inspection of blades, for material defects, and for final checking of repairs performed during overhaul. Immerse the blades in the anodizing bath as far as possible, but all parts not made of aluminum alloy must be kept out of the chromic acid bath or be separated from the blade by nonconductive wedges or hooks. Follow the anodizing treatment by a rinse in clear, cold, running water from 3 to 5 minutes, and dry the blades as quickly as possible, preferably with an air blast. Allow the dried blades to stand for at least 15 minutes before examination. Flaws (cold shuts or inclusions) will appear as fine black lines. Cracks will appear as brown stains caused by chromic acid bleeding out onto the surface. The blades may be sealed for improved corrosion resistance by immersing them in hot water (180° F. to 212° F.) for one-half hour. In no case, immerse the blades in hot water before the examination for cracks, since heat expands cracks and allows the chromic acid to be washed away.

606. ASSEMBLY. Accomplish the assembly of the propeller hub and blade in accordance with the manufacturer's recommendations. Replace clevis pins, bolts, and nuts which show wear or distortion. Never use cotter pins and safety wire a second time. The use of self-locking nuts is permissible only where originally used or approved by the manufacturer.

607.-617. RESERVED.

Section 5. ASSEMBLY OF PROPELLER TO ENGINE

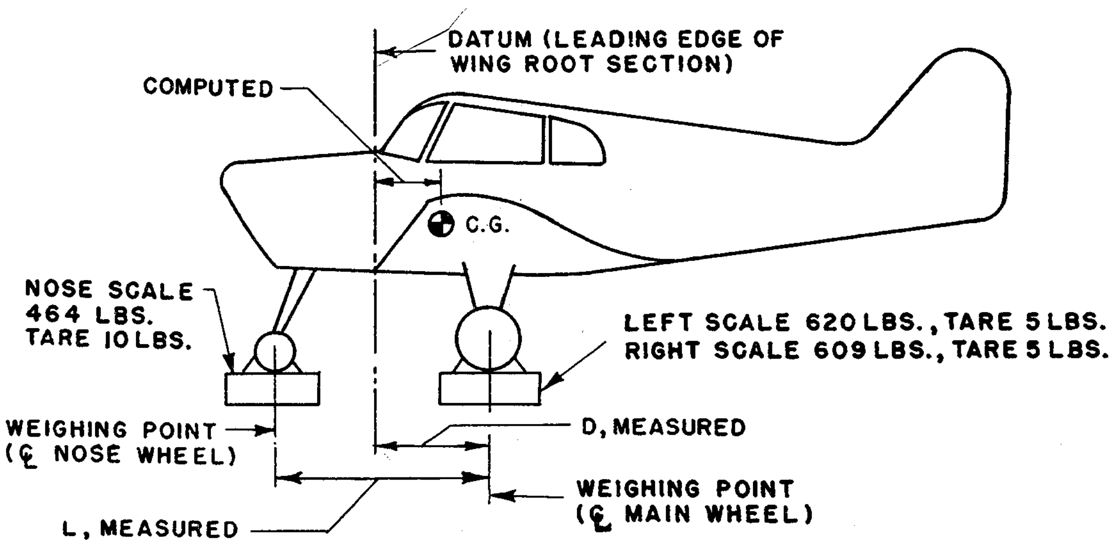
618. FIXED-PITCH PROPELLERS. Loose hub bolts and bolts installed through the lightening holes in the integral hub flange of certain engine crankshafts cause the majority of the serious difficulties experienced with fixed-pitch propellers. Either of the conditions, if not corrected, will ultimately cause the loss of the propeller.

a. *Loose hub bolts* cause elongated boltholes and damage to the hub bolts. When not corrected, the bolts break off, or friction causes enough heat to affect the glue and chars the wood. After successive running, cracks start at the boltholes. These cracks are caused, or at least accentuated, by shrinkage of the wood due to the excessive heat generated. If allowed to progress, the propeller usually flies apart or catches on fire.

b. *On some engines* equipped with a crankshaft having an integral propeller hub flange, the outer edge of the lightening holes are at the same radius as the corresponding edge of the propeller hub boltholes. When inserting the bolts through the propeller, care must be exercised so that the bolts are inserted through the proper holes in the flange. Cases have been reported where the bolts were inserted through the larger lightening holes and, accordingly, the bolt nuts bore only on the outer edges of the lightening holes. In such cases, continuous running of the propeller may cause the boltheads or nuts to slip off the flange and through the large openings in the flange, resulting in the subsequent loss of the propeller.

c. *Both the conditions discussed* above are very easy to detect, and must be corrected immediately. In case the hub flange is integral with the crankshaft, first ascertain the bolts are properly installed, then make the inspection for bolt tightness in the same manner as for any other propeller hub. Use an open-end wrench to determine hub bolt tightness; and, if the nuts can be turned, remove the cotter keys and retorque the nuts to the desired setting. Tighten hub bolts, preferably with a torque wrench, to the recommended values which usually range from 15 to 24 foot-pounds. If no torque wrench is available, an ordinary socket wrench may be used. This socket wrench should have a 1-foot extension lever and the wrench pulled up with the recommended force 12 inches away from the center of the bolt which is being tightened. The tightening is best accomplished by tightening each bolt a little at a time, being sure to tighten alternate bolts which are diametrically opposite. Exercise care not to overtighten the hub bolts, thereby damaging the wood underneath the hub flanges. Avoid the practice of overtightening bolts to draw a propeller into track. Safety the nuts by means of cottor keys of proper size or heavy safety wire twisted between each nut. A continuous length of single safety wire is not acceptable, as wire failure will result in all nuts becoming unsafetied.

619.-629. RESERVED.



TO FIND: EMPTY WEIGHT AND EMPTY WEIGHT CENTER OF GRAVITY

Datum is the leading edge of the wing (from aircraft specification)

(D) Actual measured horizontal distance from the main wheel weight point (℄ main wheel) to the Datum------- -- 34.0"

(L) Actual measured horizontal distance from the front wheel weighing point (℄ front wheel) to the main wheel weighing point---------------------------------- 67.8"

SOLVING: EMPTY WEIGHT

Weighing Point	Scale Reading #	Tare #	Net Weight
Right	609	5	604
Left	620	5	615
Front	464	10	454
Empty Weight (W)			1673

SOLVING: EMPTY WEIGHT CENTER OF GRAVITY

Formula: $C.G. = D - \frac{F \times L}{W} = 34'' - \frac{454 \times 67.8}{1673} = 34'' - 18.3'' = 15.7''$

Reference for formula, Figure 13.4.

FIGURE 13.6.—Empty weight and empty weight center-of-gravity—nose-wheel type aircraft.

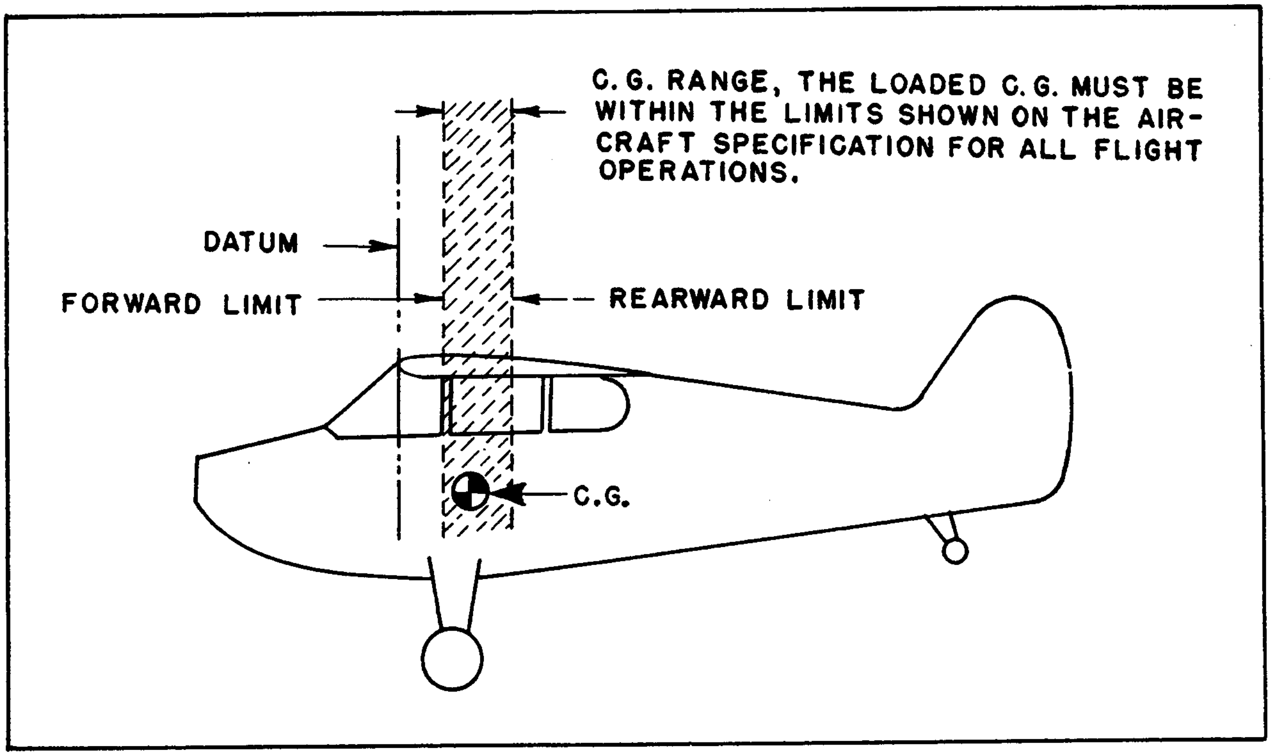


FIGURE 13.7.—Operating center-of-gravity range.

ance report when used in lieu of the landing gear. Typical locations of the weighing points are shown in figure 13.8.

n. ***Zero fuel weight*** is the maximum permissible weight of a loaded aircraft (passengers, crew, cargo, etc.) less its fuel. All weights in excess of maximum zero fuel weight must consist of usable fuel.

* **o.** ***Minimum fuel.*** Minimum fuel for balance purposes is 1/12 gallon per maximum-except-takeoff horsepower (METO), and is the maximum amount of fuel which could be used in weight and balance computations when low fuel might adversely affect the most critical balance conditions. To determine the weight of fuel in pounds divide the METO horsepower by two. *

p. ***Full Oil.*** Full oil is the quantity of oil shown in the aircraft specifications as oil capacity. Use full oil as the quantity of oil when making the loaded weight and balance computations.

q. ***Tare.*** Tare is the weight of chocks, blocks, stands, etc., used when weighing aircraft, and is included in the scale readings. Tare is deducted from the scale reading at each respective weighing point where tare is involved to obtain the actual aircraft weight.

***658. WEIGHING PROCEDURE.** Weighing procedures may vary with the aircraft and the type of weighing equipment employed. The weighing procedures contained in the manufacturing manual should be followed for each particular aircraft. Accepted procedures when weighing an aircraft are: *

a. ***Remove excessive dirt, grease, moisture, etc.,*** from the aircraft before weighing.

b. ***Weigh the aircraft*** inside a closed building to prevent error in scale reading due to wind.

c. ***To determine the c.g.,*** place the aircraft in a level flight attitude.

d. ***Have all items of equipment*** included in the certificated empty weight installed in the aircraft when weighing. These items of equipment are

* a part of the current weight and balance report. (See paragraph 662.)

e. *Properly calibrate,* zero, and use the scales in accordance with the scale manufacturer's instructions. The scales and suitable support for the aircraft, if necessary, are usually placed *

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i. *Note tare* when the aircraft is removed from the scales.

659. WEIGHT AND BALANCE COMPUTATIONS.
* It is often necessary, after completing an extensive alteration, to establish by computation that the authorized weight or c.g. limits as shown on the Type Certificate Data Sheets and Specifications (TCDS) are not exceeded. Paragraph b. explains* the significance of algebraic signs used in balance computations.

The Aircraft Specifications contain the following information relating to the subject:

- Center of gravity range.
- Empty weight c.g. range when applicable.
- Leveling means.
- Datum.
- Maximum weights.
- Number of seats and arm.
- Maximum baggage and arm.
- Fuel capacity and arm.
- Oil capacity and arm.
- Equipment items and arm.

The FAA TCDS do not list the basic required equipment prescribed by the applicable airworthiness regulations for certification. Refer to the manufacturer's equipment list for such information.

a. *Unit Weight for Weight and Balance Purposes.*

Gasoline ------------------ 6 pounds per U.S. gal.
Turbine Fuel ----------- 6.7 pounds per U.S. gal.
Lubricating oil ------ 7.5 pounds per U.S. gal.
Crew and
passengers --------------- 170 pounds per person.

b. *Algebraic Signs.* It is important to retain the proper algebraic sign (+ or -) through all balance computations. For the sake of uniformity in these computations, visualize the aircraft with the nose to the left. In this position any arm to the left (forward) of the datum is "minus" and any arm to the right (rearward) of the datum is "plus." Any item of weight added to the aircraft either side of the datum is plus weight. Any weight item removed is a minus weight. When multiplying weights by arms, the answer is plus if the signs are alike, and minus if the signs are unlike.

The following combinations are possible:

Items added forward of the datum—

(+) weight x (-) arm = (-) moment.

Items added to the rear of the datum—

(+) weight x (+) arm = (+) moment.

Items removed forward of the datum—

(-) weight x (-) arm = (+) moment.

Items removed rear of the datum—

(-) weight x (+) arm = (-) moment.

The total weight of the airplane is equal to the weight of the empty aircraft plus the weight of the items added, minus the weight of the items removed.

The total moment of the aircraft is the algebraic sum of the empty weight moment of the aircraft and all of the individual moments of the items added and/or removed.

660. WEIGHT AND BALANCE EXTREME CONDITIONS. The weight and balance extreme conditions represent the maximum forward and rearward c.g. position for the aircraft. Include the weight and balance data information showing that the c.g. of the aircraft (usually in the fully loaded condition) falls between the extreme conditions.

a. *Forward Weight and Balance Check.* When a forward weight and balance check is made, establish that neither the maximum weight nor the forward c.g. limit listed in the Aircraft Specifications is exceeded. To make this check, the following information is needed:

(1) The weights, arms, and moment of the empty aircraft.

(2) The maximum weights, arms, and moments of the items of useful load which are located ahead of the forward c.g. limit; and

(3) The minimum weights, arms, and moments of the items of useful load which are located aft of the forward c.g. limit.

*A typical example of the computation necessary to make this check, using the above data, is shown in figure 13.10.

b. ***Rearward Weight and Balance Check.*** When a rearward weight and balance check is made, establish that neither the maximum weight nor the rearward c.g. limit listed in the*

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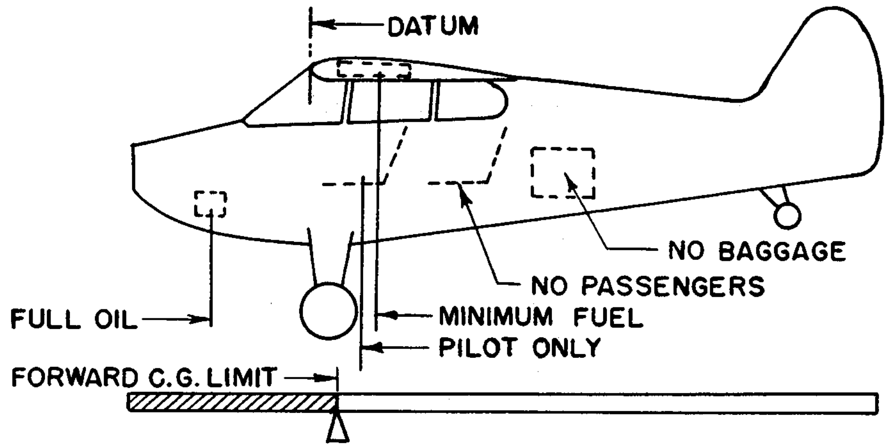

TO CHECK: MOST FORWARD WEIGHT AND BALANCE EXTREME.

GIVEN: Actual empty weight of the airplane-------------- 1169#
Empty weight center of gravity ----------------- +10.6"
*Maximum weight --------------------------- 2100#
*Forward C.G. limit -------------------------- + 8.5"
*Oil, capacity 9 qts. -------------------------- 17# at - 49
*Pilot in farthest forward seat equipped with controls (unless otherwise placarded) ----------- 170# at + 16"
*Since the fuel tank is located to the rear of the forward C.G. limit, minimum fuel should be included. $\frac{\text{METO HP}}{12} = \frac{165}{12} = 13.75$ gal. x 6# ------- 83# at + 22"

*Information should be obtained from the aircraft specification.

Note: Any items or passengers must be used if they are located ahead of the forward C.G. limit.
Full fuel must be used if the tank is located ahead of the forward C.G. limit.

CHECK OF FORWARD WEIGHT AND BALANCE EXTRE ME

	Weight (#)	x Arm (")	= Moment ("#)
Aircraft Empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Pilot	+ 170	+ 16	+ 2720
Fuel	+ 83	+ 22	+ 1826
Total	+ 1439 (TW)		+ 16104 (TM)

Divide the TM (Total Moment) by the TW (Total Weight) to obtain the forward weight and balance extreme.

$$\frac{TM}{TW} = \frac{16104}{1439} = + 11.2''$$

Since the forward C.G. limit and the maximum weight are not exceeded, the forward weight and balance extreme condition is satisfactory.

FIGURE 13.10.—Example of check of most forward weight and balance extreme.

Chapter 14. ENGINES AND FUEL SYSTEMS

Section 1. ENGINES

677. GENERAL. Persons should avail themselves of the manufacturer's manuals, service bulletins, and instruction books regarding the repair and overhaul, inspection, installation, and maintenance of aircraft engines. The repair and overhaul of engines are too many and varied for the different types and models of engines to be mentioned here in specific detail.

678. INSPECTION. All moving and/or highly-stressed parts and those subjected to high temperature should have a critical visual inspection at the time of overhaul. It is often necessary to supplement the visual inspection by employing one of the following procedures:

a. ***Wet or dry magnetic dust inspection*** of magnetic materials;

b. ***wet or dry penetrant inspection*** of nonmagnetic materials;

c. ***x-ray or sonic inspection*** of any material; or

d. ***hydrostatic inspection*** testing of fluid lines and internal passages and assemblies such as cylinder heads.

* **679. POWERPLANT SUDDEN STOPPAGE.** Sudden stoppage is a very rapid and complete stoppage of the engine. It can be caused by engine seizure or by one or more of the propeller blades striking an object in such a way that r.p.m. goes to zero in less than one complete revolution of the propeller. Sudden stoppage may occur under such conditions as complete and rapid collapse of the landing gear, nosing over the aircraft, or crash landing. Sudden stoppage can cause internal damage, such as cracked propeller gear teeth, gear train damage in the rear section, crankshaft misalignment, or damaged propeller bearings. When sudden stoppage occurs, the engine is usually replaced. Any aircraft powerplant that has been sub- * jected to sudden stoppage should be inspected to the extent necessary to assure continued safe operation. These procedures will serve as a guide for locating damage that may occur whenever an aircraft powerplant has been subjected to sudden deceleration or stoppage.

To fully evaluate any unsatisfactory findings resulting from this type of inspection, it will be necessary to refer to the applicable manufacturer's service and overhaul data. In addition, many of the prime aeronautical engine manufacturers now have specific recommendations on the subject of sudden stoppage involving their products. To assure continued airworthiness and reliability, it is essential that such data be used. In the event the manufacturer has not specified an instruction to follow, the following may be used as a guideline.

a. ***Reciprocating Engine (Direct Drive).***

(1) Powerplant Exterior Inspection. Remove the engine cowling and examine the engine for visible external damage and audible internal damage.

(a) Rotate the propeller shaft to determine any evidence of abnormal grinding or sounds.

(b) With the propeller removed, inspect the crankshaft flange or splines for signs of twisting, cracks, or other deformation. Remove the thrust-bearing nut and seal and thoroughly inspect the threaded area of the shaft for evidence of cracks.

(c) Rotate the shaft slowly in 90° increments while using a dial indicator or an equivalent instrument to check the concentricity of the shaft.

* ***(d)*** Remove the oil sump drain plug and check for metal chips and foreign material.

(e) Remove and inspect the oil screens for metal particles and contamination.

(f) Visually inspect engine case exterior for signs of oil leakage and cracks. Give particular attention to the propeller thrust-bearing area of the nose case section. *

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(g) Inspect cylinders and cylinder holddown area for cracks and oil leaks. Thoroughly investigate any indication of cracks, oil leaks or other damage.

(2) Powerplant Internal Inspection.

(a) On engines equipped with crankshaft vibration dampers, remove the cylinders necessary to inspect the dampers and inspect in accordance with the engine manufacturer's inspection and overhaul manual. When engine design permits, remove the damper pins, and examine the pins and damper liners for signs of nicks or brinelling.

(b) After removing the engine-driven accessories remove the accessory drive case and examine the accessory and supercharger drive gear train, couplings, and drive case for evidence of damage.

1. Check for cracks in the case in the area of accessory mount pads and gear shaft bosses.

2. Check the gear train for signs of cracked, broken, or brinelled teeth.

3. Check the accessory drive shaft couplings for twisted splines, misalignment and runout.

(3) Accessory and Drive Inspection. Check the drive shaft of each accessory, i.e., magnetos, generators, external supercharger, and pumps for evidence of damage.

(4) Engine Mount Inspection.

(a) Examine the engine flex mounts when applicable for looseness, distortion, or signs of tear.

(b) Inspect the engine mount structure for bent, cracked, or buckled tubes.

(c) Check the adjacent airframe structure for cracks, distortion, or wrinkles.

(d) Remove engine mount bolts and mount holddown bolts and inspect for shear, cracks, or distortion.

(5) Exhaust-driven Supercharger (Turbo) Inspection. Sudden stoppage of the powerplant can cause the heat in turbine parts to heat soak the turbine seals and bearings. This excessive heat causes carbon to develop in the seal area and varnish to form on the turbine bearings and journals.

(a) Inspect all air ducts and connections for air leaks, warpage, or cracks.

(b) Remove compressor housing and check the turbine wheel for rubbing or binding.

(6) Propeller Inspection Repair. Any propeller that has struck a foreign object during service should be promptly inspected in accordance with the propeller manufacturer's prescribed procedures for possible damage resulting from this contact with the foreign object and, if necessary, repaired according to the manufacturer's instructions. If the propeller is damaged beyond the repair limits established by the propeller manufacturer and a replacement is necessary, install the same make/model or alternate approved for this installation. Refer to the aircraft manufacturer's optional equipment list, applicable FAA Aircraft Specification, Data Sheet, or Supplemental Type Certificate Data.

b. *Reciprocating Engine (Geared Drive).* Inspect the engine, propeller and components as in preceding paragraphs.

(1) Remove the propeller reduction gear housing and inspect for:

(a) Loose, sheared, or spalled cap screws or bolts.

(b) Cracks in the case.

(2) Disassemble the gear train and inspect the propeller shaft, reduction gears and accessory drive gears for nicks, cracks, or spalling.

c. *Turbine, Engine, Ingestion Inspection.* When the components of the compressor assembly or turbine section are subjected to ingestion damage, refer to the engine manufacturer's inspection and overhaul manual for specific inspection procedures and allowable tolerances. In general, an inspection after ingestion of foreign materials consists of the following areas:

(1) Inspect the external areas of the engine cases, attached parts and engine mounts for cracks, distortion, or other damage.

(2) Inspect the turbine disc for warpage or distortion.

(3) Inspect turbine disc seal for damage from rubbing or improper clearance.

(4) Inspect compressor rotor blades and stators for nicks, cracks, or distortion.

685. WELDING OF HIGHLY STRESSED ENGINE PARTS. In general, welding of highly-stressed engine parts is not recommended for parts that were not originally welded. However, under the conditions given below, welding may be accomplished if it can be reasonably expected that the welded repair will not adversely affect the airworthiness of the engine when:

a. ***The weld*** is externally situated and can be inspected easily;

b. ***the part*** has been cracked or broken as the result of unusual loads not encountered in normal operation;

c. ***a new replacement part*** of obsolete type engine is not available; or

d. ***the welder's experience and equipment employed*** will insure a first-quality weld in the type of material to be repaired and will insure restoration of the original heat treat in heat-treated parts. Refer to Chapter 2 for information on process details.

686. WELDING OF MINOR ENGINE PARTS. Many minor parts not subjected to high stresses may be safely repaired by welding. Mounting lugs, cowl lugs, cylinder fins, covers, and many parts originally fabricated by welding are in this category. The welded part should be suitably stress-relieved after welding.

687. METALLIZING. Metallizing internal parts of aircraft engines is not acceptable unless it is proved to the FAA that the metallized part will not adversely affect the airworthiness of the engine. Metallizing the finned surfaces of steel cylinder barrels with aluminum is acceptable, since many engines are originally manufactured in this manner.

688. PLATING. Restore plating on engine parts in accordance with the manufacturer's instructions. In general, chromium plating should not be applied to highly stressed engine parts. Certain applications of this nature have been found to be satisfactory; however, engineering evaluation of the details for the processes used should be obtained.

a. ***Dense chromium plating*** of the crankpin and main journals of some small engine crankshafts has been found satisfactory, except where the crankshaft is already marginal in strength. Plating to restore worn low-stress engine parts such as accessory driven shafts and splines, propeller shaft ends, and seating surfaces of roller- and ball-type bearing races is acceptable.

b. ***Porous chromium plated walls*** of cylinder barrels have been found to be satisfactory for practically all types of engines. Dense or smooth chromium plating without roughened surfaces, on the other hand, has not been found to be generally satisfactory.

(1) Cylinder barrel pregrinding and chromium plating techniques used by the military are considered acceptable for all engines, and military approved facilities engaged in doing this work in accordance with military specifications are eligible for approval by the FAA.

(2) Chromium plated cylinder barrels have been required for some time to be identified in such a manner that the markings are visible with the cylinder installed. Military processed cylinders are banded with orange enamel above the mounting flange. It has been the practice to etch on either the flange edge or on the barrel skirt the processor's initials and cylinder oversize. Most plating facilities use the orange band as well as the permanent identification marks.

(3) A current list of engine and maximum permissible cylinder barrel oversize follows:

*

Engine manufacturer	Engine series	Maximum oversize (in.)
Air Cooled Motors (Franklin)	No oversize for sleeved cylinders..	
	Solid cylinders	0.017
Continental Motors	R-670, W-670, R9A	0.010 to 0.020
	All others	0.015
Jacobs	All	0.015
Kinner	All	0.015
Pigman, LeBlond, Rearwin, Ken Royce	All	0.025
Lycoming	All	0.010 to 0.020
Menasco	All	0.010

(Table continues on next page.) *

Engine manufacturer	Engine series	Maximum oversize (in.)
Pratt & Whitney	R-2800B, C, CA, CB	0.025
	*R-959 and R-1830..........	0.030
	All others	0.020
Ranger	6-410 early cyls. 6-390	0.010
	6-410 late cyls. 6-440 (L-440) series..	0.020
Warner	All.....................................	0.015
Wright	All.....................................	0.020

*(The above oversize limits correspond to the manufacturer's requirements, except for P&W R-985 and R-1830 series engines.)

* NOTE: Check for latest manufacturer specifications.

"688b(4). [Deleted]—Change 3" *

(5) Cylinder barrels which have been plated by an agency whose process is approved by the FAA and which have not been preground beyond maximum permissible limits will be considred acceptable for installation on certificated engines. It will be the reponsibility of the owner or the repairing agency to provide this proof. In some cases, it may be necessary to remove cylinders to determine the amount of oversize since this information may be etched on the mating surface of the cylinder base flange.

689. ENGINE ACCESSORIES. Overhaul and repair of engine accessories in accord with the engine and the accessory manufacturers' instructions are recommended.

690. CORROSION. Accomplish corrosion preventive measures for temporary and dead storage in accord with the instructions issued by the pertinent engine manufacturer. Avoid the use of strong solutions which contain strong caustic compounds and all solutions, polishes, cleaners, abrasives, etc., which might possibly promote corrosive action. (Refer to Chapter 6.)

691. ENGINE RUN-IN. After an aircraft engine has been overhauled, it is recommended that the pertinent aircraft engine manufacturer's run-in instructions be followed. Observe the manufacturer's recommendations concerning engine termperatures and other criteria.

Repair processes employed during overhaul often necessitate amending the manufacturer's run-in procedures. Follow the approved amended run-in procedures in such instances.

692. COMPRESSION TESTING OF AIRCRAFT ENGINE CYLINDERS. The purpose of testing cylinder compression is to determine the internal condition of the combustion chamber by ascertaining if any appreciable leakage is occurring.

a. ***Types of Compression Testers.*** The two basic types of compression testers currently in use are the direct compression and the differential pressure type testers. The optimum procedure would be to utilize both types of testers when checking the compression of aircraft cylinders. In this respect, it is suggested that the direct compression method be used first and the findings substantiated with the differential pressure method. This provides a cross-reference to validate the readings obtained by each method and tends to assure that the cylinder is defective before it is removed. Before beginning a compresssion test, consider the following points:

(1) When the spark plugs are removed, identify them to coincide with the cylinder. Close examination of the plugs will reveal the actual operating conditions and aid in diagnosing problems within the cylinder. Paragraph 693d. of this section contains more information on this subject.

(2) The operating and maintenance records of the engine should be reviewed. Records of previous compression tests are of assistance in determining progressive wear conditions and help to establish the necessary maintenance actions.

(3) Before beginning a compression check, precautions should be taken to prevent the accidental starting of the engine.

(b) ***Direct Compression Check.*** This type of compression test indicates the actual pressures

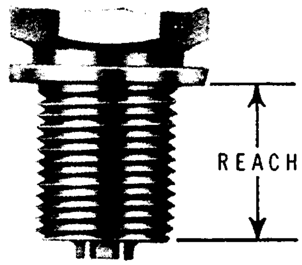

FIGURE 14.3.—Spark plug reach.

b. *Reach.* The spark plug reach (figure 14.3) is the threaded portion which is inserted into the spark plug bushing of the cylinder. A plug with the proper reach will insure that the electrode end inside the cylinder is in the best position to achieve ignition. Spark plug seizure or improper combustion within the cylinder will probably occur if a plug with the wrong reach is used.

c. *Installation Procedures.* When installing spark plugs, observe the following procedure:

(1) Visually inspect the plug for cleanliness and condition of the threads, ceramic, and electrodes.

NOTE: Never install a spark plug which has been dropped.

(2) Check the plug for the proper gap setting using a round wire feeler gauge as shown in figure 14.4. In the case of used plugs, procedures for cleaning and regapping are usually contained in the various manufacturers' manuals.

(3) Check the plug and cylinder bushing to ascertain that only one gasket is used per spark plug. When a thermocouple-type gasket is used, no other gasket is required.

(4) Apply antiseize compound sparingly to the shell threads, but do not allow the compound to contact the electrodes as the material is conductive and will short out the plug. If desired, the use of antiseize compound may be eliminated on engines equipped with stainless steel spark plug bushings or inserts.

(5) Screw the plug into the cylinder head as far as possible by hand. If the plug will not turn easily to within 2 or 3 threads of the gasket, it may be necessary to clean the threads.

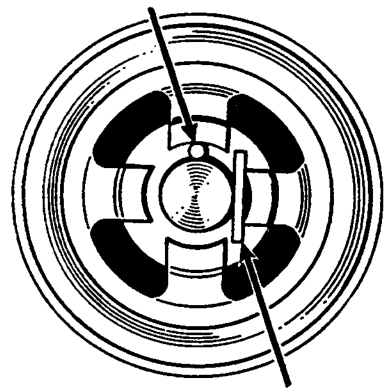

FIGURE 14.4—Method of checking spark plug gap.

NOTE: Cleaning inserts with a tap is not recommended as permanent damage to the insert may result.

(6) Seat the proper socket securely on the spark plug and tighten to the torque limit specified by the engine manufacturer before proceeding to the next plug.

Caution

A loose spark plug will not transfer heat properly and, during engine operation, may overheat to the point where the nose ceramic will become a "hot spot" and cause preignition. However, avoid overtightening as damage to the plug and bushing may result.

(7) Connect the ignition lead after wiping clean with methylethylketone (MEK), acetone, or similar material. Insert the terminal assembly into the spark plug in a straight line. (Care should be taken as improper techniques can damage the terminal sleeves.) Screw the connector nut into place until finger tight; then tighten an additional one-quarter turn while holding the elbow in the proper position.

* **Caution**

MEK is highly toxic, read label before using. *

(8) Perform an engine runup after installing a new set of spark plugs. When the engine has reached normal operating temperatures, check the magnetos and spark plugs in accordance with the manufacturer's instructions.

d. *Operational Problems.* Whenever problems develop during engine operation which appear to

* be caused by the ignition system, it is recommended that the spark plugs and ignition harnesses be checked first before working on the magnetos. The following are the most common spark plug malfunctions and are relatively easy to identify: *

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(1) Fouling.

(a) Carbon fouling (figure 14.5a) is identified by the dull black, sooty deposits on the electrode end of the plug. Although the primary causes are excessive ground idling and rich idle mixtures, plugs with a cold heat range may also be a contributing factor.

(b) Lead fouling is characterized by hard, dark, cinderlike globules which gradually fill up the electrode cavity and short out the plug. (See figure 14.5b). The primary cause for this condition is poor fuel vaporization combined with a high tetraethyl-lead content fuel. Plugs with a cold heat range may also contribute to this condition.

(c) Oil fouling is identified by a wet, black carbon deposit over the entire firing end of the plug as shown in figure 14.5c. This condition is fairly common on the lower plugs in horizontally opposed engines, and both plugs in the lower cylinders of radial engines. Oil fouling is normally caused by oil drainage past the piston rings after shutdown. However, when both spark plugs removed from the same cylinder are badly fouled with oil and carbon, some form of engine damage should be suspected, and the cylinder more closely inspected. Mild forms of oil fouling can usually be cleared up by slowly increasing power while running the engine until the deposits are burned off and the misfiring stops.

(2) Fused Electrodes. There are many different types of malfunctions which result in fused spark plug electrodes; however, most are associated with preignition either as the cause or the effect. For this reason, any time a spark plug is found with the following defects, further investigation of the cylinder and piston should be conducted.

FIGURE 14.5a.—Typical carbon fouled spark plug.

FIGURE 14.5b.—Typical lead fouled spark plug.

FIGURE 14.5c.—Typical oil fouled spark plug.

(a) Cracked Nose Ceramics. Occasionally, the ceramic nose core will crack, break away, and remain trapped behind the ground electrode. This piece of insulation material will then build up heat to the point where it will ignite the fuel/air mixture prematurely. The high temperatures and pressures encountered during this condition can cause damage to the cylinder and piston and ultimately lead to fusing and shorting out of the plug.

Chapter 15. RADIO AND ELECTRONIC SYSTEMS

Section 1. MAINTENANCE OF RADIO AND ELECTRONIC SYSTEMS

747. GENERAL. The safety of aircraft operated in the National Airspace System is dependent in a large degree upon the satisfactory performance of the airborne radio and electronic systems. Reliability and performance of the system(s) is proportional to the quality of maintenance received and the knowledge of those who perform such maintenance. It is, therefore, important that maintenance be accomplished using the best techniques and practices to assure optimum performance.

The term "system" as used in this chapter means those units of antenna, power source, sensors, receivers, transmitters, and indicators which together perform a function of communications or navigation.

This chapter is not intended to supersede or replace any Federal Aviation Administration regulation or specific manufacturer's instructions pertaining to radio and electronic equipment maintenance. Chapter 11 supplements the information provided in this chapter.

748. MAINTENANCE OF EQUIPMENT. Inspect units or radio/electronic equipment, assemblies, wiring and control systems for damage, general condition, and proper functioning to assure the continuous satisfactory operation of the system. Test, adjust, and repair radio and electronic equipment and systems in accordance with the manufacturer's maintenance instructions, manuals, and applicable Federal Aviation Regulations.

749. REPLACEMENT OF COMPONENTS. Replace damaged or defective components of radio or electronic units with identical items or items equivalent to the original in electrical and mechanical characteristics, operating tolerances, and the ability to function in the physical environmental conditions encountered in the operation of the aircraft.

750. INSPECTION OF INSTALLATIONS. Some items to look for and checks to be made during the inspection are:

a. Damaged or overheated equipment, connections, or wiring.

b. Poor electrical bonding.

c. Improper support of wiring and conduit.

d. Dirty equipment and connections.

e. Loose connections, terminals, plugs, and receptacles.

f. Condition of fuses, circuit breakers, and electric lamps.

g. Insufficient clearance of equipment from mounting rack, insecure or improper mountings.

h. Broken or missing antenna insulators, lead-through insulators, springs, safety wires, etc.

i. Miscellaneous irregularities such as loose quick-disconnects, metal objects in terminal strips or junction boxes, tightness of connections in plugs and receptacles, broken wire bundle lacing, pinched or dented conduit, broken or inadequate cable clamps, etc.

751. CLEANING. Frequent cleaning of radio and electronics equipment is recommended. Dust, dirt, and lint contribute to overheating of equipment, poor ventilation, and malfunctioning. Equipment chassis may be cleaned with a blast of dry air and a small brush. Special attention should be given that ventilation openings in equipment housings are open and free from obstructing lint and dust.

752. CONTACT CLEANERS. When cleaning radio equipment internally, spray cleaners can be used effectively, especially on switching assemblies. There are many contact cleaners on the market which, while they work well on micarta wafer switches, can cause irreparable damage to plastic wafer switches. Do not use contact cleaners on plastic wafer switches unless recommended or known to be harmless to the plastic.

753. OPERATIONAL CHECKS. An operational check is recommended during 100-hour or periodic inspections of radio and electronic systems. Although individual units of equipment may receive bench checks at various times, the proper functioning of a system can best be determined by an operational check in the aircraft. The various units of communications, navigation, weather radar, distance measuring equipment (DME), and transponder systems are interdependent upon each other for proper operational performance.

* **754. RADIO EQUIPMENT OPERATION.** Determine that the radio and electronic equipment operates satisfactorily throughout the voltage range of the aircraft electrical system under taxi, takeoff, slow cruise, normal cruise, and landing operating conditions. *

755.-765. RESERVED.

Section 1. MAINTENANCE OF WIRING AND CABLES

766. WIRING AND CABLE INTEGRITY. Inspect interconnecting wiring, cables, and conduit between various pieces of electronic equipment to determine that they do not rub against the airframe or each other under vibration conditions encountered in flight. Inspect open wiring and cabling for fraying, damage or distortion resulting from heavy objects being placed on it, being stepped on, or being used as handholds.

767. PROTECTION FROM FLUIDS. Separate wiring or cables from flammable fluids lines or those which carry fluids which have a deteriorating effect on wire insulation. Wiring or cables should be routed above such lines and securely clamped to the aircraft structure. An arcing fault between an electric cable and a fluid line may puncture the line and result in a fire.

768. WIRE AND CABLE CLAMPS. Inspect wire and cable clamps for proper tightness. Where cables pass through structure or bulkheads, inspect for proper clamping or grommets. Inspect for sufficient slack between the last clamp and the electronic equipment to prevent strain at the cable terminals and minimize adverse effects on shock mounted equipment.

769. CONDUIT. Conduit is manufactured in metallic and nonmetallic materials and in both rigid and flexible forms. Primarily its purpose is for mechanical protection of the cable within. Inspect conduit for proper end fittings, absence of abrasion at the end fittings, and proper clamping. Inspect for distortion, adequate drain points which are free of dirt, grease, or other obstructions, and freedom from abrasion or damage due to moving objects such as aircraft control cables or shifting cargo.

770. PLASTIC WIRE SLEEVING. Inspect plastic wire sleeving for damage due to abrasion, solvents, or hydraulic fluids.

* "771. [Deleted] — Change 3" *

772.-782. RESERVED.

Section 3. JUNCTION BOXES AND TERMINAL STRIPS

783. JUNCTION BOXES. Inspect junction boxes for "oil canning" of the cover and sides, internal shorts due to distortion of the box, internal cleanliness, absence of stray metallic objects, proper grommeting where wires or cables enter the box, and freedom of drain holes from foreign objects or material.

784. INTERNAL ARRANGEMENT. Electric cable inside the box should be laced or clamped in such a manner that terminals are not hidden, relay armatures are not fouled, and motion relative to any equipment is prevented. Where marginal clearances are unavoidable, an insulating material should be interposed between current-carrying parts and any grounded surface.

785. TERMINAL STRIPS. Inspect terminal strips which provide connection of radio and electronic systems to the aircraft electrical system for loose connections, metallic objects which may have fallen across the terminal strip, dirt and grease accumulation, etc. Such conditions can cause arcing which may result in a fire.

786. PLUGS AND RECEPTACLES. Inspect this type of power connector for loose soldered connections, proper insulation of metallic parts, and fraying of wires in the plug and receptacle inserts.

787.-797. RESERVED.

Section 4. POWER SOURCES AND DISTRIBUTION SYSTEMS

798. BATTERY ELECTROLYTE CORROSION. Electrolyte spilled during ground servicing should be neutralized at once with solutions of sodium bicarbonate (for acid electrolyte) or boric acid, vinegar, or a 3 percent solution of acetic acid (for alkaline electrolyte). Residue should be washed off with clean water and the area thoroughly dried.

799. GENERATORS AND ALTERNATORS. Inspect generators and alternators and their associated wiring and distribution systems for wear, damage, general condition, and proper functioning to assure the continued satisfactory operation of the electrical system. Frequent visual inspections, operating checks of all electrical circuits and equipment, and replacement or repair when deficiencies are found are effective in minimizing electrical troubles and hazards in aircraft.

800. ALTERNATOR DIODES. Alternators employ diodes for the purpose of converting the alternating current to direct current. These diodes are electronic devices and are particularly susceptible to damage if abused. A diode will allow passage of current in one direction with little resistance, but will allow passage of current in the opposite direction only if the voltage applied exceeds that value for which the device was designed. A voltage surge in the line, if it exceeds the design value, will destroy the diode very quickly.

801. DIODE PROTECTION. The best protection against diode destruction by voltage surges is to make certain that the battery is never disconnected for the aircraft electrical system when the alternator is in operation. The battery acts as a large capacitor and tends to damp out voltage surges. Make certain that the battery is never connected with reversed polarity. This will subject the diodes to a direct short circuit and will generally destroy them instantly.

802. ALTERNATOR/BATTERY CONNECTIONS. Some alternators require that the battery be connected in the circuit initially before it will produce any output.

803. STATIC ELECTRICAL POWER CONVERTERS. Static power converters employ solid state devices to convert the aircraft primary electrical source voltage to higher values for the operation of radio and electronic equipment. They contain no moving parts and are relatively maintenance free. Various types are available for AC to DC or DC to AC conversion. Exercise care in locating and mounting static converters to insure adequate ventilation for cooling purposes. Heat radiating fins should be kept clean of dirt and other foreign matter which may impair their cooling properties.

804. CLEANING AND PRESERVATION. Frequent cleaning of electrical and electronic equipment to remove dust, dirt, and grime is recommended. Fine emery cloth may be used to clean terminals and mating surfaces if they appear corroded or dirty. Crocus cloth or very fine sandpaper should be used to polish commutators or slip rings. Use of emery cloth on commutators is not acceptable because metallic particles from the cloth may cause shorting and burning.

805. MISCELLANEOUS CHECK ITEMS. Make frequent checks for miscellaneous irregularities such as loose terminal connections, poorly soldered or loosely swaged terminals, missing safety wire, loose quick-disconnects, broken wire bundle lacing, broken or inadequate wire clamps, and insufficient clearance between exposed current-carrying parts and ground. Replacement or repair should be accomplished as a part of routine maintenance.

806. ADJUSTMENT AND REPAIR. Accomplish all adjustment, repair, overhaul, and testing of electrical equipment and systems in accordance with the recommendations and procedures set forth in maintenance instructions or manuals published by the aircraft and equipment manufacturers.

807. ELECTRICAL SWITCH INSPECTION. Special attention should be given to electrical circuit switches, especially the spring-loaded type, during the course of normal airworthiness inspection. An internal failure in this type of switch may allow the switch to remain closed even though the toggle or button returns to the "off" position. During inspection, attention should also be given to the possibility that improper switch substitution may have been made.

* "808. [Transferred to paragraph 754.] — Change 3" *

809.-819. RESERVED.

Chapter 16. INSTRUMENTS

Section 1. MAINTENANCE OF INSTRUMENTS

864. GENERAL. The complexity of modern instruments, integrated flight systems, auto-pilots, air data computers, and inertial guidance systems necessitates complex maintenance procedures, sophisticated test equipment, and qualified personnel. The safety of aircraft operated in the National Airspace System is dependent in a large degree upon the satisfactory performance of airborne instrument systems. It is, therefore, important that maintenance be accomplished using the best techniques and practices to assure optimum performance.

The term "system" as used in this chapter means those units of power source, sensors, transmitters, indicator, and controllers which together perform a function of display, interpretation, or control of the functions of an aircraft, its systems, or the environment in which it operates.

* **865. DEFINITION.** The definition of an instrument means a device using an internal mechanism to show visually or aurally the attitude, altitude, or operation of an aircraft or aircraft part. It includes electronic devices for automatically controlling an aircraft in flight. *

866. MAINTENANCE OF INSTRUMENTS. Repairs and overhaul of aircraft instruments should be made only by a Federal Aviation Administration (FAA) approved facility having proper test equipment, adequate manufacturer's maintenance manuals and service bulletins, and qualified personnel. Details concerning the repair and overhaul of various instruments differ considerably. Test, repair, and adjust instruments and instrument systems in accordance with the manufacturer's maintenance instructions, manuals, and applicable Federal Aviation Regulations (FAR). Consult the airframe manufacturer for specific maintenance instructions involving instruments that are installed or supplied by them.

867. TEST/ADJUSTMENT OF INSTRUMENTS. Certain instruments, such as altimeters and vertical speed (rate of climb) indicators, are equipped with simple adjusting means. The barometric correlation adjustment should not be adjusted in the field; changing this adjustment may nullify the correspondence between the basic test equipment calibration standards and the altimeter. Additionally, correspondence between the encoding altimeter and its encoding digitizer or the associated blind encoder may be nullified. These adjustments should be accomplished by qualified personnel, using proper test equipment and adequate reference to the manufacturer's maintenance manuals.

***867-1. LIQUID QUANTITY INDICATING SYSTEM.** Any time a component is changed in a liquid quantity indication system, the system shall be calibrated. This applies to all aircraft liquid systems such as fuel, oil, alcohol, etc. Refer to applicable aircraft maintenance manual for procedures. *

868. REPLACEMENT OF COMPONENTS. Replace damaged or defective instruments with identical serviceable components or components equivalent to the original in electrical and mechanical characteristics, operating tolerances, and the ability to function in the physical environmental conditions encountered in the operation of the aircraft. The replacement of instruments with other than identical or optional approved instruments may require FAA approval. Consult type certificate data sheet or parts manual. Be sure all shipping plugs and gyro caging devices that may have been installed for shipping purposes are removed before installing an instrument. Check new installations carefully prior to applying electrical power or connecting test equipment to avoid damaging sensitive mechanisms. Test the new instrument after installation for proper functioning (where applicable).

869.-879. RESERVED.

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Section 4. PITOT-STATIC SYSTEMS

907. SYSTEM COMPONENTS. Conventional design of the pitot-static system consists of pitot-static tubes or pitot tubes with static pressure ports or vents and their related heaters, if any, and includes lines, tubing, water drains and traps, and selector valves. Pressure actuated indicators such as the altimeter, airspeed, and rate-of-climb indicators, and control units such as air data transducers, and automatic pilots may be connected to the system.

908. PITOT-STATIC TUBES AND LINES. The pitot tube is installed with the axis parallel to the longitudinal axis of the aircraft unless otherwise specified by the manufacturer. When lines are attached or removed from a bulkhead feed-through fitting or at a union, precautions must be taken to assure that the line attached to the opposite end is not loosened, twisted, or damaged by rotation of the fitting. Such fittings normally are provided with a hex flange for holding.

909. PRESSURE PORTS OR VENTS. Static pressure ports or vents should be mounted flush with the fuselage skin. Inspect for elevation or depression of the port or vent fitting. Such elevation or depression may cause airflow disturbances at high speeds and result in erroneous airspeed indications.

910. CLEANING OF SYSTEM. Inspect air passages in the systems for water, paint, dirt, or other foreign matter. Probe the drains in the pitot tube to remove dirt or other obstructions. Tubing diameter should be checked when a problem is experienced with drainage of the pitot-static system or freezing at altitude. If this diameter is less than 3/8 inch, it should be replaced with larger tubing. Water may not drain freely from smaller diameter lines. Water or obstructions may be removed from the lines by disconnecting them near the instrument and blowing clean, dry air through them. No instruments should be connected to the system during this process.

911. HEATER ELEMENTS. Some pitot-static tubes have replaced heater elements, while others do not have replaceable elements. Check replacement of the heater element or the entire tube for proper operation by noting either ammeter current or that the tube or port gets hot to the touch.

912. SYSTEM LEAK TESTING. Pitot-static leak tests should be made with all instruments connected to assure that no leaks occur at instrument connections. Such tests should be made whenever a connection has been loosened or an instrument replaced.

***913. STATIC SYSTEM TEST.** Advisory Circular AC 43-203B describes an acceptable means of complying with static system tests required by FAR Part 91, Section 91.171 and 91.172, for airplanes operated in controlled airspace under the instrument flight rule (IFR). (This circular also provides information concerning the test equipment used, and precautions to be taken when performing such tests.) Aircraft not operated in controlled airspace under IFR should be tested in accordance with the aircraft manufacturer's instructions. *

If the manufacturer has not issued instructions for testing static systems, the following may be used:

a. Connect the test equipment directly to the static ports, if practicable. Otherwise, connect to a static system drain or tee connection and seal off the static ports. If the test equipment is connected to the static system at any point other than the static port, it should be made at a point where the connection may be readily inspected for system integrity. Observe testing precautions given in paragraph 915.

b. ***Apply a vacuum*** equivalent to 1,000 feet altitude, (differential pressure of approximately 1.07 inches of mercury or 14.5 inches of water) and hold.

c. ***After one minute, check*** to see that the leakage has not exceeded the equivalent of 100 feet of altitude (decrease in differential pressure of approximately 0.105 inches of mercury or 1.43 inches of water).

914. PITOT SYSTEM TEST. Pitot systems should be tested in accordance with the aircraft manufacturer's instructions. If the manufacturer has not issued instructions for testing pitot systems, the following may be used:

a. ***Test the pitot system*** by sealing the drain holes and connecting the pitot pressure openings to a tee to which a source of pressure and a manometer or reliable airspeed indicator is connected.

b. ***Apply pressure*** to cause the airspeed indicator to indicate 150 knots (differential pressure 1.1 inches of mercury or 14.9 inches of water), hold at this point and clamp off source of pressure. After 1 minute, the leakage should not exceed 10 knots (decrease in differential pressure of approximately 0.15 inches of mercury or 2.04 inches of water). **Warning: Do not apply suction to pitot lines.**

915. PRECAUTIONS IN TESTING. Observe the following precautions in all pitot-static system leak testing:

a. ***Perform all other work*** and inspections before leak testing.

b. ***Use a system diagram.*** It will prevent applying reverse pressure to any instrument, and help determine the location of a leak while observing instrument indications.

c. ***Be certain that no leaks exist in the test equipment.***

d. ***Run full range tests only if you are thoroughly familiar*** with the aircraft instrument system and the test equipment.

e. ***Pressure in the pitot system*** must always be equal to or greater than that in the static system. A negative differential pressure across an airspeed indicator can damage it.

f. ***The rate of change or the pressure applied*** should not exceed the design limits of any pitot or static instruments connected to the systems.

g. ***After the conclusion of the leak test,*** be certain that the system is returned to its normal flying configuration, such as removing tape from static ports and pitot tube drain holes and replacing the drain plugs, etc.

916.-926. RESERVED.

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